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[625. 113]

The systematic adjustment of curve pegging by the correction of the versines,[1]

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Figs. 1 to 5, pp. 912 to 914.

The methods of adjustment of the curves by correction of the versines have been devised especially for retracing the curves on lines in service in order to limit as far as possible lining the track and without having, in addition, to move the track at those points where it is not possible to line the tracks.

Consequently these methods substitute for the layout orginally pegged out and generally comprising an arc of circle of single radius connected to the tangents at its ends by correct parabolic transition curves, several arcs of circle of different radii connected to the tangents and sometimes together by more or less correct parabolic transition curves.

It then becomes necessary, in order not to deform a pegging in which it is desired to correct certain imperfections due to the negligence of the staff, to use a method of rectification giving a diagram of the versines corresponding to the geometrical characteristics of the layout.

Mr. *Cassan's* method satisfies this requirement when the curve of constant radius is connected to the tangents by Nordling parabolic transition curves [2].

As we know in order to insert these transitions the tangent is moved parallelly by the amount $\frac{p^2}{6R}$, or the arc of circle by $\frac{p^2}{6R'}$; in this latter case, the radius of arc of circle is equal to $R' = R - \frac{p^2}{6R'}$.

As the *Cassan* method gives however a constant radius in the circular part, it cannot be employed when, instead of

(1) Translated from the French.

(2) The formula for this curve was invented in 1865 by Mr. Chavès, Engineer (A. & M.), Engineer of the French Nord Railway.

using Nordling transitions, use is made of Cambier transitions which are inserted between the tangent undisplaced and an arc of circle of radius $R' < R$ replacing for a certain length the arc of circle of radius R.

Indeed, in this case the circular part of the curve is no longer of constant radius but comprises at each end an arc of circle of radius $R' < R$ and in the remaining central part, the arc of circle of radius R undisplaced.

As a result, the regularisation of a layout of this kind by the *Cassan* method involves the displacement of the whole curve of radius R and in consequence involves displacements of no utility.

On the other hand, as on lines in service the use of the Cambier transitions is very frequent, it would be interesting to imagine a method of adjustment applicable to their layout.

This is the reason for this note.

It will meet our object if we complete Mr. *Cassan*'s method.

Let us repeat, without giving any proofs [1], the principles upon which they rest, which principles moreover are those of other methods though expressed in a different manner :

1. Every curve imaginable has its diagram of curvatures and consequently of versines peculiar to it. Inversely to every diagram we can think of, there corresponds a well defined curve;

2. If we take (fig. 1) two curves of any form C and C′ both connecting together the same tangents A_0T and B_0T, the area

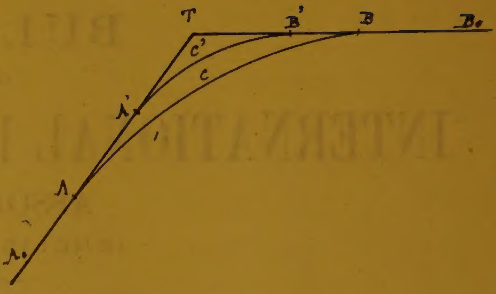


Fig. 1.

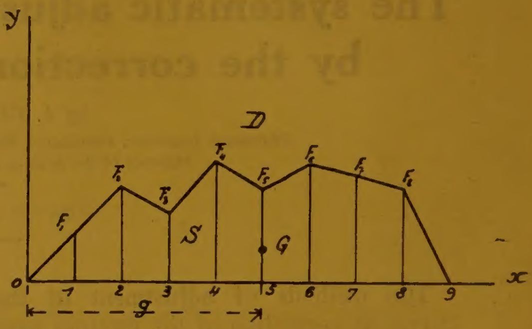


Fig. 2.

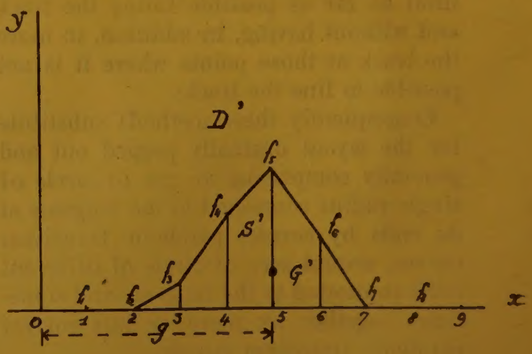


Fig. 3.

S (fig. 2) lying between the diagram D′ of the curve C′ and the axis of the abscissæ is equal to the area S′ (fig. 3) be-

(1) See *Méthodes de rectification du tracé des courbes de chemins de fer par correction des flèches (Methods of adjusting railway curves by correction of the versines)* by J. Chappellet. Eyrolles, Publisher, Paris.

tween the diagram D′ of the curve C′ and the axis of the abscissæ, and this no matter what curves C and C′ may be.

The sum of the versines from which the diagram D is drawn is equal to the sum of the versines of the diagram D′;

3. The areas S and S′ have their centres of gravity G and G′ at the same distance g from the base. This distance or abscissa of the centre of gravity is easily obtained by taking the sum of the products $f_1 + 2f_2 + 3f_3 + 4f_4 + \dots\dots + nf_n$ and then dividing this sum by the sum of the versines $f_1 + f_2 + f_3 + f_4 + \dots\dots + f_n$.

The desired abscissa is obtained in multiples of the equidistance or constant distance between the pegs.

From these principles the following corollaries can be deduced :

1. If the curve be symmetrical, its diagram is also symmetrical and this relatively to the ordinate through the centre of gravity;

2. For two tangents all the symmetrical curves connecting them together have diagrams the areas of which are equal one to the other and which are all symmetrical relatively to a given ordinate, the geometric position of their centres of gravity.

Let us now consider the modification to be made to the *Cassan* method.

Let us suppose we have traced out by abscissæ and ordinates a curve of 1 000 metres radius connected to the tangents by Cambier parabolic transition curves 75 metres long.

Figure 4 shows the layout at the beginning and the end of the curve.

The pegs being 10 metres apart, let us suppose that as a result of negligence in the pegging the versines shown in dotted lines on the rather irregular diagram of figure 5 have been measured.

A regular diagram corresponding to the geometric characteristics of the layout must be substituted for this diagram.

We know the centres of gravity of the

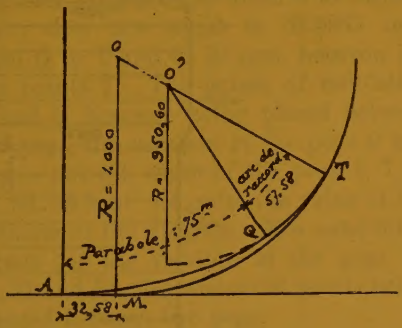


Fig. 4.

Explanation of French terms:
Parabole = Parabola. — Arc de raccord = Connecting arc.

two diagrams should have the same abscissa g which we will first of all calculate.

We have :

$$g = \frac{46\,203}{1981} = 23.3231 = 233.231 \text{ metres},$$

46 203 being the sum of the moments of the versines relatively to the peg 0;

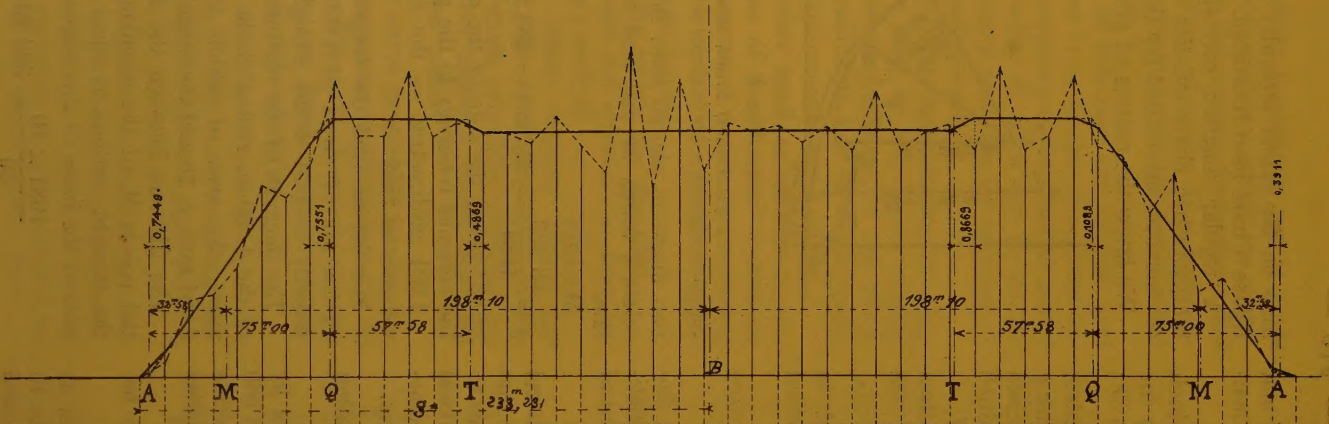
1 981 millimetres = the sum of the versines as read.

Now let us find the tangential points of the arc of circle of 1 000-m. radius directly tangent to the straight sections.

The diagram of the versines of the arc of the 1 000-m. radius circle is a trapezium, the area of which is equal to 1 981 mm. × 10 and the height to 50 mm.

The distance between the two tangential points M, of the circular curve and the straight sections, is equal to half the sum of the bases of this trapezium *i. e.* to

$$\frac{1981 \times 10}{50} = 396.20 \text{ m.}$$



Numéros des piquets	0	1	2	3	4	5	6	7	8	9	10	11
Flèches actuelles	0	3	16	17	23	40	37	44	60	49	49	61
Flèches nouvelles	0	5,1	12,8	19,2	26,3	33,3	40,3	47,3	52,6	52,6	52,6	52,6

Numéros des piquets	12	13	14	15	16	17	18	19	20	21	22	23
Flèches actuelles	49	52	50	50	48	54	48	42	66	38	60	42
Flèches nouvelles	52,6	52,6	50,4	50	50	50	50	50	50	50	50	50

Numéros des piquets	24	25	26	27	28	29	30	31	32	33	34	35
Flèches actuelles	52	50	51	48	51	46	58	46	50	51	46	63
Flèches nouvelles	50	50	50	50	50	50	50	50	50	50	52,6	52,6

Numéros des piquets	36	37	38	39	40	41	42	43	44	45	46	47
Flèches actuelles	46	49	61	47	45	33	41	17	20	11	1	0
Flèches nouvelles	52,6	52,6	52,6	51,8	44,8	37,7	30,8	23,8	16,8	9,8	2,8	0

Fig. 5.

Explanation of French terms :

Numéros des piquets = Numbers of the pegs. — Flèches actuelles = Actual versines.
Flèches nouvelles = New versines.

The tangential points M being placed symmetrically in relation to the ordinate through the centre of gravity which also determines the point B common to the arc of circle and to the bisector of the angle at the summit, therefore lie at :

$$\frac{396.2}{2} = 198.10 \text{ m.}$$

on each side of their ordinate, or of the point B.

It is now easy to draw on the diagram of the heights of arc recorded (dotted line), figure 5, the diagram of the theoretical heights corresponding to a perfect pegging out of the 1 000-m. radius curve (full line). We know actually that the start A of the parabolic transition curves is situated at a distance of 32.58 m. from the tangential points M, that they are 75 m. long, that the arc of circle of radius $R' = 950.60$ m. needed to insert the parabolic transition curves between the 1 000-m. radius curve and the straight sections, have a developed length of 57.58 m. and that their versine is equal to 52.5983 mm. for a chord of 20 m.

Moreover, from A to Q the versines lengthen progressively from 0 to 52.5983 mm.; they are equal to 52.5983 mm. from Q to T and to 50 mm. between the two points T. The points of osculation A and Q however being placed between two pegs, the versines at the pegs 0 and 47 are not nil, those of the pegs 1, 7, 8, 46, 39, 38 have not quite the value of the ordinate of the diagram. The same thing occurs for the versines at the pegs 13, 14, 33 and 34, the tangential points being situated between two pegs.

Let us repeat briefly the formulæ by which the values of these versines can be calculated :

For F_0 and f_{47} : $f_0 = \frac{K}{6} N^3$ (1).

For f_1 and f_{46} : $f_B = \frac{K}{6}\left[(1 + N)^3 - 2N^3\right]$,

For f_7 and f_{39} : $f_P = f - \frac{K}{6}\left[(1 + M)^3 - 2M^3\right]$,

For f_8 and f_{38} : $f_T = f - \frac{K}{6} M^3$,

For f_{14} and f_{34} : $f_A = \frac{1}{2}\left[(1 + N)^2 f_2 + (1 - N)^2 f_1\right] - N^2 f_2$,

For f_{13} and f_{33} : $f_B = \frac{1}{2}\left[(2 - N)^2 f_1 + N^2 f_2\right] - (1 - N)^2 f_1$.

In the present case, for f_0 : $N = 0.7449$.
For f_{47} : $N = 0.3911$.
For f_7 and f_8 : $M = 0.7551$.
For f_{39} and f_{38} : $M = 0.1089$.
For f_{13} and f_{14} : $N = 0.4869$.
For f_{33} and f_{34} : $N = 0.8669$.

The new versines being calculated, the amounts by which the pegs of the existing curve have to be moved to bring them to the position for the correct curve will be arrived at by getting the differences between the old heights f and the new F

(1) We have made use of the notation corresponding to figures 29, 30, 31, 15, of our article published in the September 1930 number of the *Bulletin of the International Railway Congress Association*.

Tableau des calculs

Nos des δ	Nos des piquets	Flèches relevées sur le terrain f	Produit de la flèche relevée par le N° du piquet	Flèches calculées F	Différences f – F = δ	Somme des δ de la colonne 6 (interligne)	Somme des nombres de la colonne 7 (½ déplacement)	Variations	Différences δ définitives Somme des nombres des col. 6 et 9	Somme des δ de la colonne 10 (interligne)	Somme des nombres de la colonne 11 (½ déplacement)	Déplacement	Flèches nouvelles définitives Différence entre les nombres des colonnes 3 et 10
1	2	3	4	5	6	7	8	9	10	11	12	13	14
47	0	0	0	0	0				0				
						0				0			
46	1	3	3	5.2	– 2.2		0	+ 0.1	– 2.1		0	0	5.1
						– 2.2				– 2.1			
45	2	16	32	12.2	+ 3.8		– 2.2		+ 3.8		– 2.1	– 4	*mêmes*
						+ 1.6				+ 1.7			
44	3	17	51	19.2	– 2.2		– 0.6		– 2.2		– 0.4	– 1	
						– 0.6				– 0.5			
43	4	23	92	26.3	– 3.3		– 1.2		– 3.3		– 0.9	– 2	
						– 3.9				– 3.8			
42	5	40	200	33.3	+ 6.7		– 5.1		+ 6.7		– 4.7	– 9.5	
						+ 2.8				+ 2.9			
41	6	37	222	40.3	– 3.3		– 2.3		– 3.3		– 1.8	– 3.5	
						– 0.5				– 0.4			
40	7	44	308	47.3	– 3.3		– 2.8		– 3.3		– 2.2	– 4.4	*valeurs*
						– 3.8				– 3.7			
39	8	60	480	52.6	+ 7.4		– 6.6		+ 7.4		– 5.9	– 11	
						+ 3.6				+ 3.7			
38	9	49	441	52.6	– 3.6		– 3.		– 3.6		– 2.2	– 4.5	
						0				+ 0.1			
37	10	49	490	52.6	– 3.6		– 3.		– 3.6		– 2.1	– 4	
						– 3.6				– 3.5			
36	11	61	671	52.6	+ 8.4		– 6.6		+ 8.4		– 5.6	– 11	
						+ 4.8				+ 4.9			
35	12	49	588	52.6	– 3.6		– 1.8		– 3.6		– 0.7	– 1.5	*que*
						+ 1.2				+ 1.3			
34	13	52	676	52.6	– 0.6		– 0.6		– 0.6		+ 0.6	+ 1.2	
						+ 0.6				+ 0.7			
33	14	50	700	50.4	– 0.4		0		– 0.4		+ 1.3	+ 2.5	
						+ 0.2				+ 0.3			
32	15	50	750	50	0		+ 0.2		0		+ 1.6	+ 3	
						+ 0.2				+ 0.3			
31	16	48	768	50	– 2		+ 0.4		– 2		+ 1.9	+ 4	
						– 1.8				– 1.7			
30	17	54	918	50	+ 4		– 1.4		+ 4		+ 0.2	+ 0.5	*celles*
						+ 2.2				+ 2.3			
29	18	48	864	50	– 2		+ 0.8		– 2		+ 2.5	+ 5	
						+ 0.2				+ 0.3			
28	19	42	798	50	– 8		+ 1.		– 8		+ 2.8	+ 5.5	
						– 7.8				– 7.7			
27	20	66	1.320	50	+ 16		– 6.8		+ 16		– 4.9	– 10	
						+ 8.2				+ 8.3			
26	21	38	798	50	– 12		+ 1.4		– 12		+ 3.4	+ 7	
						– 3.8				– 3.7			
25	22	60	1.320	50	+ 10		– 2.4		+ 10		– 0.3	– 0.5	
						+ 6.2				+ 6.3			
24	23	42	966	50	– 8		+ 3.8		– 8		+ 6	+ 12	*indiquées*
						– 1.8				– 1.7			
23	24	52	1.248	50	+ 2		+ 2.		+ 2		+ 4.3	+ 8.5	
						+ 0.2				+ 0.3			
22	25	50	1.250	50	0		+ 2.2		0		+ 4.6	+ 9	
						+ 0.2				+ 0.3			
21	26	51	1.326	50	+ 1		+ 2.4		+ 1		+ 4.9	+ 10	
						+ 1.2				+ 1.3			
20	27	48	1.296	50	– 2		+ 3.6		– 2		+ 6.2	+ 12.5	
						– 0.8				– 0.7			
19	28	51	1.428	50	+ 1		+ 2.8		+ 1		+ 5.5	+ 11	*dans*
						+ 0.2				+ 0.3			
18	29	46	1.334	50	– 4		+ 3.		– 4		+ 5.8	+ 11.5	
						– 3.8				– 3.7			
17	30	58	1.740	50	+ 8		– 0.8		+ 8		+ 2.1	+ 4	
						+ 4.2				+ 4.3			
16	31	46	1.426	50	– 4		+ 3.4		– 4		+ 6.4	+ 13	
						+ 0.2				+ 0.3			
15	32	50	1.600	50	0		+ 3.6		0		+ 6.7	+ 13.5	
						+ 0.2				+ 0.3			
14	33	51	1.683	50	+ 1		+ 3.8		+ 1		+ 7	+ 14	*la*
						+ 1.2				+ 1.3			
13	34	46	1.564	52.6	– 6.6		+ 5.		– 6.6		+ 8.3	+ 16.5	
						– 5.4				– 5.3			
12	35	63	2.205	52.6	+ 10.4		– 0.4		+ 10.4		+ 3	+ 6	
						+ 5.				+ 5.1			
11	36	46	1.656	52.6	– 6.6		+ 4.6		– 6.6		+ 8.1	+ 16	
						– 1.6				– 1.5			
10	37	49	1.813	52.6	– 3.6		+ 3.		– 3.6		+ 6.6	+ 13	*colonne 5*
						– 5.2				– 5.1			
9	38	61	2.318	52.6	+ 8.4		– 2.2		+ 8.4		+ 1.5	+ 3	
						+ 3.2				+ 3.3			
8	39	47	1.833	51.8	– 4.8		+ 1.		– 4.8		+ 4.8	+ 9.5	
						– 1.6				– 1.5			
7	40	45	1.800	44.8	+ 0.2		– 0.6		+ 0.2		+ 3.3	+ 3.5	
						– 1.4				– 1.3			
6	41	33	1.353	37.8	– 4.8		– 2.	+ 0.1	– 4.7		+ 2	+ 4	37.7
						– 6.2				– 6			
5	42	41	1.722	30.8	+ 10.2		– 8.2		+ 10.2		– 4	– 8	
						+ 4.				+ 4.2			
4	43	17	731	23.8	– 6.8		– 4.2		– 6.8		+ 0.2	+ 0.5	
						– 2.8				– 2.6			
3	44	20	880	16.8	+ 3.2		– 7.		+ 3.2		– 2.4	– 5	
						+ 0.4				+ 0.6			
2	45	11	495	9.7	+ 1.3		– 6.6	– 0.1	+ 1.2		+ 1.8	+ 3.5	9.8
						+ 1.7				+ 1.8			
1	46	1	46	2.7	– 1.7		– 4.9	– 0.1	– 1.8		0	0	2.8
						0				0			
0	47	0	0	0							0		
		1981	46.203	1981									

Explanation of headings, etc. of table on opposite page :

Top = Table of calculations.
Column 1 = Nos. of the δ's.
— 2 = Nos. of the pegs.
— 3 = Versines measured on the site f.
— 4 = Product of the versine measured by the number of the peg.
— 5 = Calculated versines F.
— 6 = Differences $f - F = \delta$.
— 7 = Sum of the δ's of column 6 (between lines).
— 8 = Sum of the numbers of column 7 (1/2 displacements).

Column 9 = Variations.
— 10 = Definitive differences δ. Sum of columns 6 and 9.
— 11 = Sum of the δ's of column 10 (between lines).
— 12 = Sum of the numbers of column 11 (1/2 displacements).
— 13 = Displacements.
— 14, *heading* = New definitive versines. Differences between the numbers of columns 3 and 10.
—, *lower down* = Same values as those indicated in column 5.

(column 6 of the table), by adding in turn these differences (column 7) then taking the sum of the numbers so obtained (column 8); the partial totals are the half-displacements required.

In order to get a rigorously correct pegging, the values of the versines which are not in whole millimetres should be calculated to several places of decimals, four for example.

As a consequence the calculation of the lining of the track is very laborious. It is therefore desirable to see if it is possible to obtain in practice a correct curve whilst simplifying the calculations.

To begin with, a simplification is realised when the conditions of the layout are such that the osculation points A and Q and the tangential points T coincide with the pegs as then the above given formulæ become considerably simplified.

This however is a special case.

Now experience shows that a very satisfactory result is obtained by calculating the value of the new versines not to four places of decimals, but to one and that if need be they can be calculated to the nearest millimetre or half millimetre. The calculations then become very easy. The sum of the new versines are made equal to that of the old : in the example given it was only necessary to increase versine 14 by 0.4 mm.

The last correction of the line (last number of column 8) is no longer nil but its small value is cancelled out, the more readily the greater the number of pegs, by modifying some of the versines by a fraction of a millimetre or a millimetre (corrector groups of the Hallade method).

In the example dealt with (see table of calculations above) at each peg the value of the new versine is equal to the ordinate of the diagram of the theoretical versines drawn by taking into consideration the geometrical characteristics of the layout.

As the versines in the parabolic transition curves and the circular arcs of 950.60 m. radius, the value of which does not correspond to a whole number of millimetres, are given to one place of decimals instead of four, it would have been superfluous to alter the heights f_0, f_1, f_7, f_8, f_{13}, f_{14}, f_{33}, f_{34}, f_{38}, f_{39}, f_{46}, f_{47}, by using the formulæ repeated on page 915.

Consequently the last column of collumn 8 is not nil (it would have been had the versines been calculated to four places of decimals) but equal to 4.9 mm.

This amount is readily cancelled out by correcting by + 0.1 mm. the differences δ_{46} and δ_6, and by — 0.1 mm. the differences δ_2 and δ_1.

Actually we have :

$$0.1\,(46 + 6) - 0.1\,(1 + 2) = + 4.9$$

and

$$- 4.9 + 4.9 = 0.$$

This is the application of the Hallade corrector couples.

In practice therefore, the original versines are not altered.

If the evaluation of the new heights had been to the nearest millimetre or half millimetre, the last number of column 8 would have been 71 mm. To cancel it out would have entailed modifying by 1.4 mm. the new versines first obtained which again would be quite acceptable.

Nevertheless when the curve is very short, it is of interest to make the calculations to several places of decimals, four at most, because owing to the corrector couples having only a short lever arm the modification of the new theoretical versines can be sufficiently large to deform appreciably the diagram of the theoretical versines. It is true that in this case the calculations to several places of decimals are relatively easy seeing that the development of the curve is small.

The object of evaluating the versines to one or several decimals is not to get very great accuracy in the value of the versines, which would be of little use, but to get the last number of column 8 as small as possible so that it may be easy to cancel it out.

Again the attention of the men doing the work should be drawn to the importance of conserving very closely, especially about the tangent or osculating points, the direction of the straight sections tangent to the curves at the time of placing the pegs by means of the abscissæ and ordinates, so that at a later date, the measurement of the versines at each tangent or osculation point is really based on the straight section which was used to give the angle at the summit of the curve.

If this important requirement is not followed the regularisation by correction of the versines of a curve pegged by abscissæ and ordinates would result in laying in another curve of the same radius, tangential to straight sections different to the first: this would tend to increase the lining up.

To some extent this remark explains why the *Cassan* method has often not given really good results on lines in operation in all cases where it was possible to apply it, the straight sections given by the lines of rails not having always remained in the direction of those put down when the railway was built. It is only just to add that the extensive lining up shown necessary by this method is above all due to the defective pegging out originally through, for example, an error in evaluating the angle at the summit.

As regards the rectification of the curves of lines in service calculated by means of one of the different methods using variable and progressive radii, it remains necessary for reasons analogous to those just given to preserve in an unvarying position the pegs by means of which the two first and the two last versines can be measured.

We would point out too, that the *Cambier* parabolic transition curves laid in at the end of a curve may not be of the same length whereas the *Nordling* transitions should always be symmetrical.

The usefulness of this note is appreciated when there is little room for lining up as for example in alterations to the lines in a station.

As an end to this article we will consider the layout of a curve forming an arc of circle without parabolic transitions, and one of several tangent arcs of circle whether or not connected to one another and to the straight sections by parabolic transition curves.

Taking the case of an arc of circle without parabolic transition curves, the abscissa g of the centre of gravity of the diagram of the versines and the position of the tangent points are calculated as has just been done by the *Cassan* method.

When each of the tangent points coincides with a peg, the versine at this latter is equal without appreciable error to half the versine of the arc of circle for a chord equal to two equidistances d.

The diagram of the versines is as a result an isoceles triangle.

This is a special case, the development of a curve rarely being a multiple of the equisdistances d usually taken as equal to 10 mm.

As a general rule the tangent points do not each coincide with a peg. This would be the case of the points M of our example if we wanted to peg out the curve without parabolic transitions.

The versines at the pegs immediately preceding and following the tangent points M [the pegs 3, 4, 43, 44 (1) of our example] are calculated from the formulæ :

$$f_o = \frac{f}{2} N^2$$

$$f_A = \frac{f}{2} [(N + 1)^2 - 2N^2].$$

The new versines having been determined calculations are made as we have shown in our example.

When the layout comprises several tangent arcs of circle whether or not connected together by parabolic transitions, or of other transition curves, the diagram of the new versines is made as before by determining the abscissæ of the centres of gravity and the position of the tangent and osculation points.

The *Cassan* method, completed in this way, enables all layouts to be carried out in practice with great precision.

Seeing it involves no trial and error and that we have made the calculations easy, we think its use is always to be preferred to that of the other methods each time a new pegging has to be corrected.

(1) Formulæ given on pages 2008 and 2009 in our article in the September 1930 number of the *Bulletin of the International Railway Congress Association.*

[625. 215]

The riding qualities of railway coaches,

by P. L. HENDERSON, B. E., A. S. T. C. (Sci.),
Assistant Engineer, New South Wales Government Railways.

Figs. 1 to 13, pp. 921 to 929.

(*The Railway Engineer.*)

During the past century great advances have been made in all branches of railway engineering, and railway carriages have increased in size and comfort. It nevertheless remains true that very little is known of the fundamentals making for comfortable riding carriage which underlie the design of carriage bogies. Present-day designs must be regarded more as « the survival of the fittest » than as the result of careful theoretical calculations based on scientific investigation; and this especially applies in the case of such parts of the bogie as the length and angle of the swing links.

There appears to have been little research conducted on this subject, yet its importance, as presumably no one will question, is very great indeed, especially when it is remembered that the capital value of passenger rolling stock in the world to-day amounts to many millions of pounds sterling. The riding quality of a railway carriage depends principally on the bogie used under it and consequently this forms the chief item to be considered.

The author's purpose in preparing this article was that of describing some research word carried out by him at the Research Laboratory of the New South Wales Government Railways at Sydney, Australia. The term « bogie » is used by British engineers, while American engineers refer to the same thing as a « truck ». The bogie or truck was first introduced with the idea of making the negotiation of curves by locomotives and railway carriages easier. In 1812 William Chapman, a civil engineer, obtained an English patent, No. 3632, for a four-wheel swivelling truck, or bogie. In 1828 when a commission of American engineers visited Newcastle, Robert Stephenson recommended them to adopt the truck for engines. The first designers of a swivelling truck which was used for locomotives appear to be two Americans, John B. Jervis and Ross Winans. The former generally appears to be given the credit of being the first, and his work dated about 1831. It was a long time before the swivelling truck was introduced into English locomotive practice. The engines made about 1846 for the South Devon Line were probably the first to be fitted with it.

Suggested scheme of research work.

In studying the riding qualities of railway carriages, it was considered that the following subjects should form the basis of the research work :

1. Design of apparatus to record the movements of the component parts of a bogie when in traffic.

2. Maximum movements of springs in service.

3. Range of stress of springs in service.

4. Measurement of swing of swing bolster.

5. Study of existing instruments such as the Hallade register, Wimperis accelerometer, etc., in relation to carriage riding.

6. Vertical periodicities.

7. Rolling and pitching periodicities.

8. Spring design and action.

9. Different spring systems in carriages.

10. Static properties of springs in relation to actual practice.

11. Mechanics of the bogie.

12. Effect of angle of swing links.

13. Effect of length of swing links.

14. Returning forces given by swing bolster.

15. Effect of height of centre of gravity on car oscillation.

16. Analysis of forces involved in taking a car around a curve.

17. Transfer of forces from track to bogie and to car.

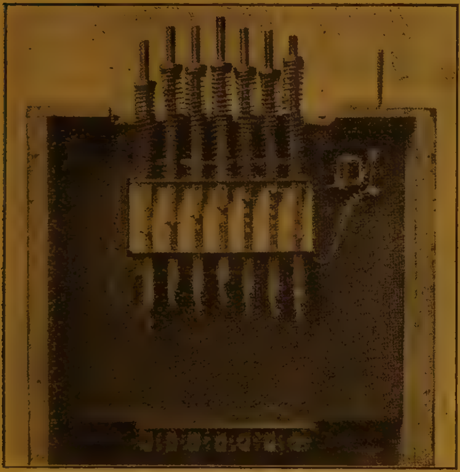


Fig. 1. — Front view.

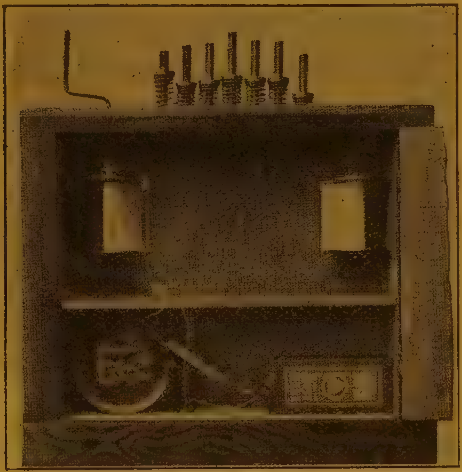


Fig. 2. — Back view.

Figs. 1 and 2. — Bogie movement recording apparatus.

18. Sway action possible on the straight.

19. Analysis of track qualities, staggered and parallel joints.

20. Effect of length of rails.

21. Effect of flange wear.

22. Gyroscopic effect of wheels and action caused by superelevation in turning to left and right in relation to direction of revolution of wheels.

In the short time at the author's disposal it was not possible to investigate all the above items, but rather it seemed better to concentrate on one or two items. With this end in view, the principal item chosen for research work was the one of recording simultaneously the various movements in a railway carriage bogie whilst in service. Seven movements of a trailer bogie of an all-steel electric passenger carriage and a time graph were recorded, whilst the carriage was running as a part of a train on the suburban electric railways between Sydney and Oatley, a run of nearly 20 miles.

Bogie movement recording apparatus.

Apparatus designed and largely made by the author for recording bogie movements is shown in figures 1 and 2. It consists of seven brass rods of 1/2 inch square section, placed 1 1/4 inches apart, which can slide vertically in square holes in two angle brackets. To one end of each of these rods is attached a Bowden wire by means of a thumb screw, the other end of the rod being 1/2 inch screwed, carrying a nut by means of which the tension on the resisting springs can be adjusted. Each rod has five 1/4-inch diameter threaded holes to receive a recording pencil, which consists of a short length of tube, with a pencil and spring inside, and on top a wing nut with which to adjust the pressure of the pencil on the paper. The casing of the Bowden wires is held in clamps on the apparatus as shown. The recording mechanism consists of a spool of paper 3 1/2 inches wide, turned by hand, and by taking care quite a good graph was obtained. It was intended to fit a motor to the apparatus at a later date. The timing device, which worked perfectly, consisted of an alarm clock and an ordinary electric bell, arranged as shown. By this arrangement intervals of twelve 1/2 or 1/3 seconds could be obtained. The method of recording the bogie movements is to use Bowden wires and pulleys. Bowden wires alone were tried, but did not prove successful, as the full movement was not recorded. This was proved by a laboratory test in which two Bowden wires, one 18 inches straight and the other 11 feet long with three curves, were used to record the same movement, but the resulting curves were not the same, so it was decided to use wires and pulleys. On the chart, which is 3 1/2 inches wide, seven bogie movements and a time graph were recorded.

Fig. 3. — Showing method of attaching wires and pulleys to a carriage bogie.

The movements recorded were :

1. — *Triple elliptical bolster spring.*
(Movement « C » on graphs.)

To measure this movement a short 1/2-inch diameter bolt was electrically welded on to the spring plank at A, figure 3. A Bowden wire was soldered in-

to a small groove cut in a 1/2-inch diameter nut, and then screwed on to the bolt. The wire from A went through a short piece of Bowden casing fixed at one end to the top buckle of the bolster spring, and at the other end to the bogie frame at B. The wire then went over a pulley C, which was held on an electrically welded bracket; from here the wire passed to the general assembly block at D, where the wire passed under a pulley, and then entered a length of Bowden casing which was fixed in a clamp just above the pulley. The other end of the casing, which was about 2 feet 6 inches long, was fixed in the clamp on the instrument shown in figure 1. The instrument was fixed to the carriage floor, just over the general assembly block D, a seat being temporarily removed to accommodate the instrument.

2. — *Swing of swing bolster.*
(Movement « G » on graphs.)

A wire was fixed just below A, figure 3, in a similar fashion to that at A, from thence it was brought over pulley E, pulley F, to the general assembly block D, and thence to the instrument.

3. — *Second triple elliptical bolster spring.* (Movement « A » on graphs.)

The wire was fixed to the spring plank in a similar way to that at A, then brought through a piece of Bowden casing fixed at one end to the top buckle of the spring, the other end being fixed to the bogie frame, the wire then came over pulley G, pulley H, and up to the instrument through the general assembly block D.

4. — *Axle-box No. 1.*
(Movement « D » on graphs.)

The movement of the axle-box gave a combination of the movement of the laminated spring and the two helical springs, which constituted the axle-box springing. A wire was taken from J, in figure 3, over pulley K and up through the general assembly block D as previously described.

5. — *Axle-box No. 2.*
(Movement « E » on graphs.)

A Bowden wire was fixed at L, and then through Bowden casing fixed at M straight to the instrument.

6. — *Axle-box No. 3.*
(Movement « F » on graphs.)

A wire was fixed to the laminated spring buckle, and then brought over a pulley N, around pulley O, and up through general assembly block D to the instrument.

7. — *Auxiliary side bearing spring.*
(Movement « B » on graphs.)

To measure this movement, a wire was attached in the usual manner at P and then through the Bowden casing fixed to bogie frame at R and thence to the instrument. No pulleys were used in this case, as the wire could be taken in very nearly a straight path.

8. — *Time graph.*
(Movement « H » on graphs.)

The time graph gives intervals of 12 seconds.

Experiments carried out with the apparatus.

The bogie movement recording apparatus was placed in an electric trailer car No. T 4422, as shown in figure 4, a seat being removed to accomodate it. Bowden wires were connected up as in figure 3. The electric trailer car was run on the Illawarra line between Sydney and Oatley as a part of an ordinary electric passenger train. The first tests were

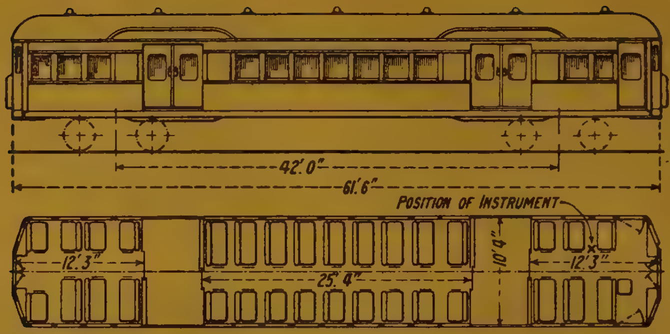


Fig. 4. — Showing position of instrument in the carriage.

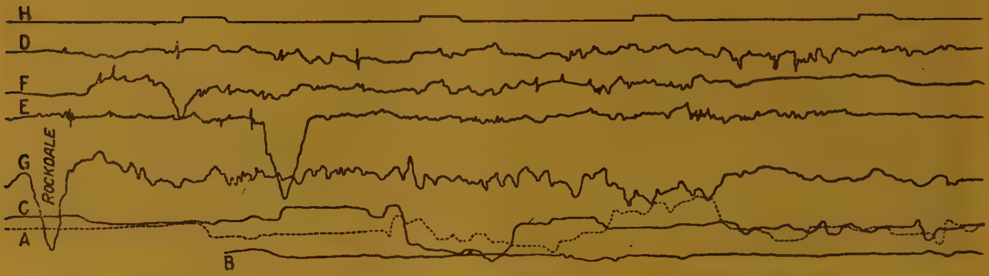


Fig. 5. — Portion of an original chart from bogie movement recording apparatus.

Note. — The graphs (figs. 5, 6, 8, 10 and 11) are reproduced at a reduced scale — 3/4 of original.

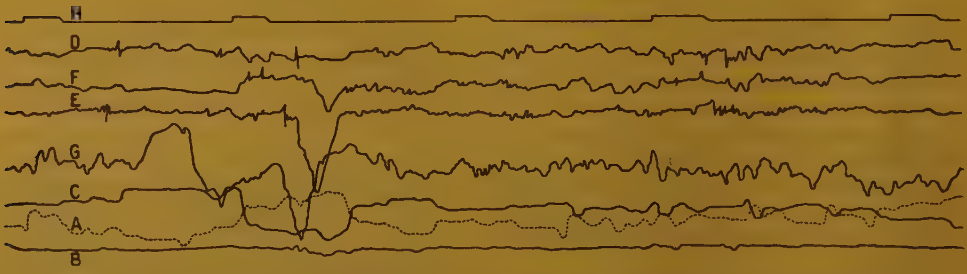


Fig. 6. — This is figure 1 retraced so as to cut out the 1 1/4-inch lag in the movements.

carried out on 14 February 1929, with very satisfactory results. A portion of the original chart as taken on the apparatus is shown in figure 5. The movements on this chart have a lag of 1 1/4 inches relative to one another. The chart has been retraced bringing each graph into a position such that any point on one curve corresponds to a point on a curve directly above or below it, and is thus shown in figure 6. On examining the graphs it will be seen that the right

and left bolster spring curves are mirror images of each other. The curve representing the spring of the swing bolster will be found to correspond to the left bolster spring. The graph of the axle-box movement on one of the graphs was found to correspond to rail joints at 40-foot intervals for a speed of 37 miles per hour of the train. Other points of interest will be seen on referring to the graphs.

From an analysis of the charts we can get :

A. — *For springs.*

1. The number of vibrations per hour of positive or negative deflections of a given magnitude.

2. The stress in lb. per square inch corresponding to these deflections.

3. The value of the maximum positive or negative deflection of the spring.

4. The range of stress in the spring in lb. per square inch.

B. — *Swing bolster.*

The magnitude of the swing of the swing bolster can be measured, and restoring forces, etc., called into play for various speeds and conditions of track, can be determined.

Finally, by using the instrument to record other movements of the bogie not yet recorded, further investigation of bogie design could be carried out.

It is recommended that for future experiments :

1. Additions be added to be apparatus so that the speed of the train be recorded.

2. A hand-operated marker be added to record mile-posts, so as to be able to locate curves and straights of the railway line on the chart.

3. Pointers should be added to the apparatus, which would draw straight lines along the chart corresponding to the position of the various movements when the carriage is at rest on a level. These lines would then act as datum or « mean » lines for calculation purposes.

4. A wider chart be used, and operated by a motor in place of being turned by hand.

Analysis of bogie movement charts.

A. — *Springs.*

The method of analysing the chart for spring movement will be shown by examining a portion of the chart for the triple elliptical bolster spring.

The mean line of the graph for the movement was obtained by drawing a line parallel to one edge of the chart, and then, by means of a planimeter, the area was measured between this line and the graph of the movement. By dividing this area by the total length of the chart, the position of the mean line was determined. This mean line corresponds to the static deflection due to the weight of the carriage. This static deflection is arrived at as follows :

	Engl. tons.
Weight of trailer car	34
Add portion of weight of passengers.	4
Total. . .	38
Less weight of two bogies	12
	26

Load on each bolster spring $= \dfrac{26}{4} \times 2\,240$ lb. $= 14\,560$ lb. On referring to the load-deflection graph (see fig. 7), for this bolster spring, the deflection is seen to be 5 inches for a load of 14 560 lb. on the unloading limb of the curve. But as the spring has friction, the actual stress is greater than that given by 14 560 lb., and is got by taking a point directly above on the mean line of the curves, which gives 15 500 lb. as the load giving 5 inches deflection. The stress in

the spring corresponding to this static load of 15 500 lb. is next calculated.

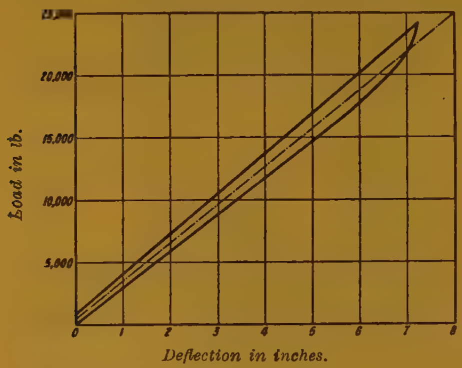


Fig. 7. — Load-deflection graph for bolster spring.

Stress « f » in lb. per square inch is :

$$f = \frac{\text{Bending moment}}{\text{Section modulus}}$$

$$= \frac{1/4\ W.\,l}{n/6\ b.\,d^2}$$

$$= \frac{3\,W.\,l}{2\,nbd^2}$$

where W = Load in lb.

l = Length of spring in inches.

n = Number of plates.

d = Thickness of plates in inches.

Stress in bolster spring for a load of

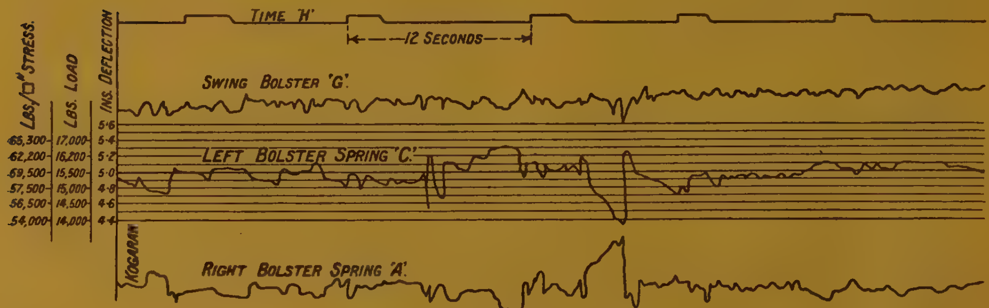


Fig. 8. — Showing bolster spring movement with stress scale.

15 500 lb., having eight plates 3 inches × 1/2 inch × 3 ft. 10 in., triple elliptic,

$$= \frac{3}{2}\ \frac{\frac{15\,500}{3} \times 46}{8 \times 3 \times (1/2)^2}$$

$$= 59\,500 \text{ lb. per sq. inch.}$$

Having now the load, deflection and stress for this mean line, a scale can be constructed, as shown on the chart, see figure 8. The range of stress, etc., can now be read directly off the chart, as the graphs are recorded full size. The static deflection of the bolster spring was measured on the bogie, with the carriage empty, and corresponded very nearly with that calculated.

B. — *Swing links.*

The lateral movement of the end of the swing links is given to a full-size scale on the original chart. It can be seen that the motion of a swing bolster is not a rythmic swing as might be expected, but rather it is a swing of an irregular character, suggesting that it has been brought about by violent lateral shocks applied to the bogie.

Relation between amplitude of oscillation and the number of times it is attained per hour.

To determine the amplitude of vibration and the number of times it is attained per hour, a portion of a bogie movement chart was analysed for the bolster spring oscillations. The following results were obtained, and are plotted in graphical form in figure 9 :

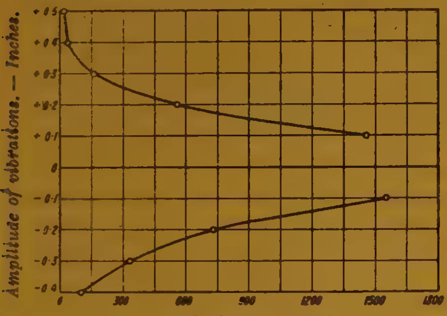


Fig. 9.

Amplitude of vibrations	Vibrations per hour.
+ 0.5″	5
0.4	35
0.3	155
0.2	560
0.1	1 465
— 0.1″	1 555
0.2	725
0.3	325
0.4	95
0.5	0

The working of stresses of springs in traffic can be correlated to the stresses in laboratory tests of the springs under

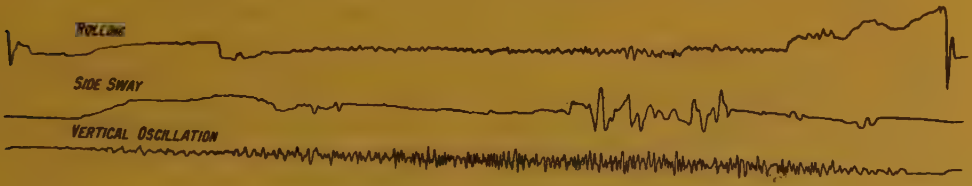


Fig. 10. — Hallade chart for a Sydney suburban electric train.

repeated loadings. Thus, from the laboratory test of a spring of given design, the maximum range of stress which can be imposed on the spring for an indefinite number of times without fracture taking place can be determined, and from the bogie test the number of times per hour this stress will take place can be determined. It is thus possible to predict the life of a spring under normal traffic conditions.

Study of existing instruments such as Hallade register.

It was decided to make an examination of any existing instruments that in any way recorded the riding qualities of cars, as such instruments would prove valuable when used in conjunction with the author's instrument in studying carriage problems. The three available were :

1. Hallade register.
2. Wimperis recording accelerometer.
3. Crocker oscillation recorder.

As space will not permit of discussing them all, the Hallade register only will be considered.

The Hallade register consists of a number of pendulums which can swing in two planes at right angles, and connected to the pendulums through lever systems are three tracers, which record the movements on a paper chart. The paper chart is worked through the instrument auto-

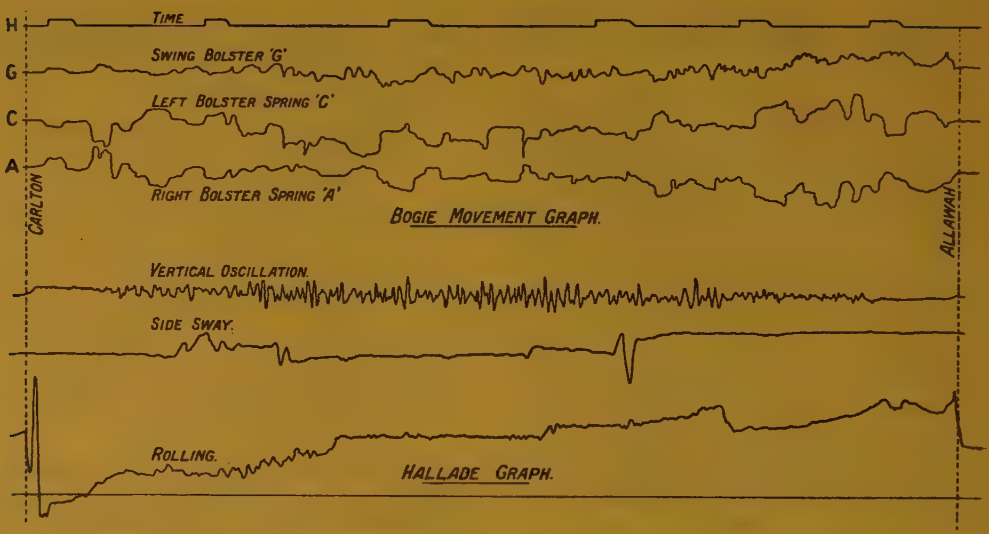


Fig. 11. — Comparison of bogie movement and Hallade graphs, recorded simultaneously.

matically by clockwork mechanism. The Hallade register is placed on the carriage floor, and records rolling, side sway, and vertical oscillations. This instrument was tried in a number of different railway carriages on the railways of New South Wales and Victoria, and a number of very interesting graphs were obtained, that in figure 10 being an example of one obtained on the Sydney suburban electric trains. In figure 11 will be seen a chart from this instrument alongside one from the bogie movement apparatus, which were taken simultaneously in the same carriage. It is difficult to see any relationship between the two records. For studying carriage problems, the Hallade register could be greatly improved by having the magnitude of the natural period of oscillation of its pendulums further removed from the magnitudes of the periods of vibrations one desires to measure in railway carriages.

Time of oscillation of springs.

In designing springs for railway carriages, the author is of the opinion that more attention should be given to the time of oscillation of springs, resulting in better riding carriages.

From experiments conducted with the Hallade register the following values were obtained :

TYPE OF BOGIE.	Vertical period.	Lateral period.	Rolling period.
Melbourne electric car :	Sec.	Sec	Sec.
Channel-sided bogie . .	0.72	1.07	1.0
Plate frame bogie . . .	0.65	0.94	0.77
Cast steel bogie	0.70	1.11	0.80
Express from Melbourne :			
Six-wheel equalised bogie	0 69	—	1.0
Victorian dining car :			
Channel-sided bogie . .	0 50	1.2	0.90
N. S. W. sleeping car :			
Six-wheel equalised bogie	0.63	—	0.95
Sydney electric car :			
Trailer bogie	0.69	—	—

The times of oscillation given in the above table are only approximate; the blanks in the table indicate that the times for these cases could not be obtained with sufficient accuracy to warrant putting down a figure for them. The time of oscillation of a railway carriage that would give good riding has not been definitely fixed to the knowledge of the writer. Sandars, in his excellent book on *Laminated Springs*, recommends the following values of periodicity :

Locomotives . .	from 250	to	150		All when fully loaded.
Coaching stock.	» 130	»	90		
Freight stock. .	» 220	»	150		
Tramcars	» 222	»	150		

Taking the periodicity of coaching stock of 130 to 90 and converting to time of vibration gives 0.46 to 0.67 seconds, which figures appear somewhat low. To get good riding the vertical time of oscillation would require to be somewhat of the order of 0.7 to 1.0 second.

Mechanics of carriage bogies.

In the following table is collected the length « A », angle of rake « B », etc., for

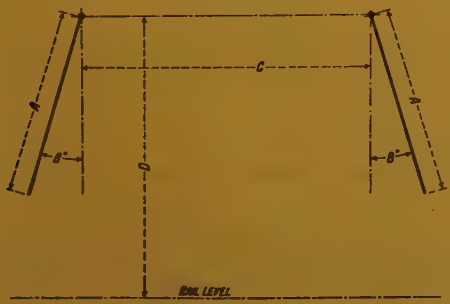


Fig. 12.

swing links of bogies used on railways in different parts of the world. From a study of the table it is evident that there is little uniformity of ideas in swing link design, and this is due to the fact that the subject has been starved of scientific investigation. The object of the swinging bolster is to minimise to some extent the curves and inequalities of the track, which cause lateral shocks. From an examination of the designs of many bogies, and also from a thorough searching of engineering literature, there ap-

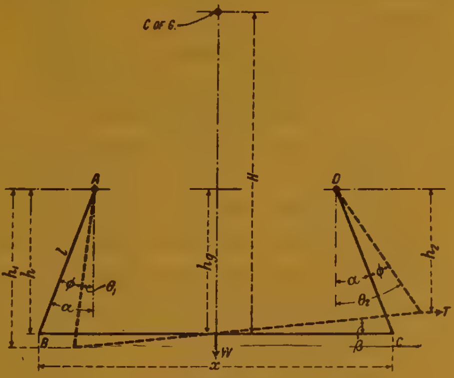


Fig. 13.

pears to be no fixed rule adopted in general for the design of the length and angle of swing links. When a swing bolster is displaced laterally, restoring forces are called into play tending to restore equilibrium, and it will now be shown that the magnitude of these forces is more affected by the length of link than by its angle of rake.

In the above figure let AB and DC represent the swing links and BC the spring plank of a swing bolster. It is desired to calculate, first, the amount the centre of gravity of the carriage rises for a given swing through angle ϕ of the swing links.

Case 1. — Inclined links.

Let l = length of link and α = angle rake.

Then $h = l \cos \alpha$

$h_1 = l \cos \theta_1$

$h_2 = l \cos \theta_2$

$h_g = 1/2 l (\cos \theta_1 + \cos \theta_2)$

$= l \cos \alpha \,.\, \cos \phi$

NAME OF RAILWAY.	A.	B.	C.	D	E (1).
Pullman Co., U. S. A.	21″	8°	58 1/4″	—	4′ 8 1/2″
Tanganyika Railway	16″	7°	69″	-	3′ 3 3/8″
French Railways	10″	10°	54″	—	4′ 9″
German Railways	9″	nil.	57″	—	4′ 8 1/2″
London & North Eastern Railway (double bolster)	18″	14°	55″	—	4′ 8 1/2″
London Midland & Scottish Railway	14 1/2″	6°	55″	—	4′ 8 1/2″
New South Wales 7-foot wheelbase (bulb angle)	15 1/4″	9°	54 1/4″	21 1/2″	4′ 8 1/2″
New South Wales I beam solebar	15 1/4″	11°	53 1/4″	21 3/4″	4′ 8 1/2″
New South Wales electric trailer bogie.	15 1/4″	11°	53 1/4″	21″	4′ 8 1/2″
New South Wales 9-foot motor bogie	21 1/8″	7°	45 3/4″	33″	4′ 8 1/2″
Victorian channel side (motor)	17 1/16″	7° 36′	55″	30″	5′ 3″
Victorian cast-steel (motor)	17 1/8″	6° 42′	64″	—	5′ 3″
Victorian plate-frame (motor)	17 1/16″	7° 35′	55″	29″	5′ 3″
Victorian channel side (trailer)	20″	7° 11′	50″	—	5′ 3″
Victorian six-wheel bogie	17 1/2″	4° 55′	52″	—	5′ 3″
Victorian Pullman sleeper	21 1/2″	8° 1′	64 3/4″	—	5′ 3″
Illinois Central sleeper	20″	6° 0′	53″	32″	4′ 8 1/2″
Illinois Central (motor bogie)	17 1/2″	6° 34′	54 1/2″	—	4′ 8 1/2″
Illinois Central	21 1/2″	5° 20′	53″	—	4′ 8 1/2″
Baldwin Loco. Works (trailer)	22 5/8″	4° 30′	47″	30 1/2″	4′ 8 1/2″
Baldwin Loco. Works (motor)	18 3/4″	11°	49″	30 1/2″	4′ 8 1/2′
Pennsylvania Railway	9″	nil.	79″	22″	4′ 8 1/2″
Canadian Pacific	20 1/2″	6° 30′	57 3/4″	30″	4′ 8 1/2″
Buenos Ayres Pacific	21″	nil.	63″	28 1/2″	5′ 6″
Leeds Forge Company	12″	8° 30′	54″	31″	4′ 8 1/2″
Queensland (pressed-steel)	13″	6° 38′	39″	20 3/4″	3′ 6″
Central Argentine	18″	nil.	70″	28 1/2″	5′ 6″
Central Argentine	9 1/4″	5°	64″	24″	5′ 6″
South Australia (4-wheel bogie)	23″	5°	65″	36″	5′ 6″
South Australia (6-wheel bogie)	22″	7° 50′	56″	31″	4′ 8 1/2″

(1) Gauge of railway.

$\therefore$ Rise of C of G of spring plank

$$= l \cos \alpha - l \cos \alpha . \cos \phi$$
$$= l \cos \alpha (1 - \cos \phi)$$

For all practical purposes the angles ϕ on either side of A and D may be taken as equal.

The above is very nearly the amount the centre of gravity of the car moves, but is slightly less on account of the following correction :

Vertical distances between ends of deflected links

$$= h_1 - h_2$$
$$= l (\cos \theta_1 - \cos \theta_2)$$
$$= 2 l \sin \alpha . \sin \phi$$
$$\therefore \sin \beta = \frac{2 l \sin \alpha . \sin \phi}{x}$$

Centre of gravity of carriage drops H $(1 - \cos \beta)$.

$\therefore$ Net rise of centre of gravity for a deflection ϕ of swing links

$$= l \cos \alpha (1 - \cos \phi) - \text{H} (1 - \cos \beta)$$

where $\beta = \sin^{-1}\left(\frac{2 l \sin \alpha . \sin \phi}{x}\right)$

Case 2. — Vertical links.

For a vertical link of length « h » and deflected through an angle θ the C of G rises an amount h $(1 - \cos \theta)$.

Case 3. — Restoring forces, with inclined links, considering gravity alone to act.

Consider the weight of the carriage to act through the centre of gravity. Using the notation of the above figure,

Let W = portion of weight of carriage on one bogie, and T = restoring force.

Let l = length of link.

With regard to W, we may neglect the X co-ordinate,

$$y = l \cos \alpha (1 - \cos \phi) - \text{H} (1 - \cos \beta).$$

The work done by W in a small displacement δy is

$$- \text{W} \delta y \quad \text{or}$$

$$\text{W}\delta y = \text{W} (l \cos \alpha \sin \phi . \delta \phi - \text{H} \sin \beta . \delta \beta),$$

$$\text{but } \sin \beta = \frac{2 l \sin \alpha . \sin \phi}{x}$$

$$\therefore \cos \beta . \delta\beta = \frac{2 l \sin \alpha}{x} . \cos \phi . \delta \phi$$

Cos β is very approximately equal to 1.

$$\therefore \delta \beta = \frac{2 l \sin \alpha}{x} . \cos \phi . \delta \phi$$

$$\therefore \text{W} \delta y = \text{W} \left\{ l \cos \alpha . \sin \phi - \frac{\text{H} \quad 4 l^2}{x^2} \sin^2 \alpha . \sin \phi . \cos \phi \right\} \delta \phi$$

$$= \text{W} l \left(\cos \alpha - \frac{4 l \text{H} \sin^2 \alpha}{x^2} . \cos \phi\right) \sin \phi . \delta \phi.$$

With regard to T, we may neglect the Y co-ordinate,

$$x = \sin (\alpha + \phi).$$

The work done by T is T δ X or

$$\text{T} . \delta x = \text{T} l \cos (\alpha + \phi) . \delta \phi$$

$$\therefore \text{T} l \cos (\alpha + \phi) . \delta \phi$$

$$= \text{W} l \left(\cos \alpha - \frac{4 l \text{H} . \sin^2 \alpha . \cos \phi}{x^2}\right) \sin \phi . \delta \phi .$$

$\therefore$ Restoring force,

$$\text{T} = \frac{\text{W} \left(\cos \alpha - \frac{4 l \text{H} \sin^2 \alpha . \cos \phi}{x^2}\right) \sin \phi .}{\cos (\alpha + \phi)}$$

$$= \frac{\text{W} \cos \alpha . \sin \phi}{(\cos) \alpha + \phi)} \text{ to a first approximation.}$$

Case 4. — Restoring forces with vertical links, considering gravity alone to act.

From similar reasoning to the above, it can be shown that in this case, T = W tan ϕ, where ϕ = angle through which the link is deflected.

In considering an actual case, it will be found that when gravity alone acts, the restoring forces for a 15 1/4-inch link having a rake of 11° is about 5 % greater than that for a vertical link of the same length, but by using a vertical link sligthly shorter, it is possible to get the same restoring force for the same amount of lateral movement of the bolster. It will be found that the restoring force is much more affected by the length of the link than by its angle of rake.

While it may be said that the inclined link is nearly universal, yet the writer is of the opinion that the vertical link has much in its favour. The basis for this opinion is that when a carriage is rounding a curve at excessive speed the bolster swings over to some position of equilibrium, where the additional centrifugal force is balanced by the restoring force called into play and remains there temporarily, and this action is similar for both inclined or vertical links.

But consider the case when the carriage is travelling on the straight, and a small irregularity in one rail of the track is met with, which causes an upward force to be applied to one side of the bolster. With the inclined link a horizontal component will act tending to displace the bolster to one side, but with the vertical link there is no horizontal component, so the bolster remains stationary, the vertical motion in this case being damped by the laminated springs either over the axle-boxes or on the bolster as the case may be. Another disadvantage of the inclined link is that, when a carriage is entering a curve, the outer wheel of the leading bogie becomes raised due to the super-elevation, with the result that a twisting couple is applied to the carriage due to overloading on diagonally opposite corners. The magnitude of this twisting couple for inclined links can be arrived at as follows :

Consider springs placed at B and C in the above figure. Then, when the bolster swings over to dotted position shown, one spring is compressed and the other becomes elongated.

Compression of spring at C $= l \sin \alpha \,.\, \sin \phi$.

Elongation of spring at B $= l \sin \alpha \,.\, \sin \phi$.

Let K = constant defining spring stiffness.

Then total twisting couple $= x\,l\,K \,.\, \sin \alpha \,.\, \sin \phi$.

In extreme circumstances this twisting couple can amount to some thousands of foot-pounds, whereas with the vertical link this effect is absent, which is another point in favour of the vertical link. Also with the inclined link it is fairly apparent that more rolling must take place.

Conclusion.

The author trusts that his attempts at solving some of the problems associated with railway carriage bogies may arouse interest in a subject that badly needs scientific investigation to bring it into line with the great advances that have been made in other branches of railway science.

He desires to thank the Railway Commissioners of New South Wales, Australia, for permission to use Departmental drawings, photographs and results of tests; also to thank the Assistant Chief Mechanical Engineer and the Research Engineer for help and encouragement.

Painting the Quebec bridge.

Figs. 1 to 4, pp. 935 to 938.

(From *Railway Engineering and Maintenance.*)

Whether considered from the standpoint of size, difficulties presented or methods employed, probably the most outstanding and interesting railway bridge painting project on the North American continent is the Quebec bridge of the Canadian National over the St. Lawrence river, near Quebec, Canada. This bridge, which is of the cantilever type and has the longest and heaviest riveted span of any bridge in the world, contains 66 480 tons of structural steel, the surface of which requires 7 500 gallons of paint for a single coat, while 70 gallons of paint are required for a single coat for each of the four main posts.

Special features of interest in connection with the painting of the bridge are the use of a chromate content paint, green in color, and the fact that, in spite of the use of up-to-date spray painting equipment on most of the work, and a working season extending from the middle of May until the last week in September of each year, it requires three years to give the bridge a single coat. Other features of interest are the unusual difficulties encountered in the work, including the hazard of working from 100 to 405 feet above the river, and the favorable results which have been accomplished by the methods employed during the last four years.

Details of bridge.

The Quebec bridge, which has two main cantilever arms supporting a through truss suspended span over the river channel, is a two-track structure, with two 5-foot sidewalks, and a 16-foot roadway between the tracks. This bridge, which was completed in September 1917, forms a link connecting the Canadian National lines on the south shore of the St. Lawrence river with those on the north, and shortens the railway mileage from Winnipeg to Halifax by about 200 miles.

In order that one unfamiliar with the bridge may fully sense its size and the magnitude of the work involved in its maintenance, as well as the hazards, the following dimensions are given :

Length of suspended span . . .	640	feet.
Length of cantilever arms . . .	580	—
Length of anchor arms	515	—
Total length of steel work . . .	3 239	—
Distance center to center of main span	1 800	—
Width center to center of main trusses	88	—
Width center to center of railway tracks	32 ft. 6 in.	
Depth center to center of chords of suspended span at center. .	110	feet.
Depth of suspended span at hip.	70	—
Depth of cantilever arm at end.	70	—
Height of main posts, center to center of pins	310	—
Depth of anchor arms at anchor piers	70	—
Height of suspended span above high water	150	—
Height of suspended span above low water	172	—

Height of south main pier above foundation	128 feet.
Height of north main pier above foundation	108 —
Height of south anchor pier above foundation	141 —
Height of north anchor pier above foundation	160 —

The Forth bridge, over the Firth of Forth in Scotland, with which the Quebec bridge may be readily compared because of its similarity of type, has an overall length of 7 870 ft. 8 in., with two clear spans of 1 700 feet each. Other details of this bridge, which was completed in March, 1890, are included in an article which appeared in *Railway Engineering and Maintenance* for October, 1930.

Maintenance work on the Quebec bridge to the present time has been largely one of painting. Up to 1926 spot painting had been sufficient to keep the structure fully protected, the work being done with a relatively small force of men, using the brush method exclusively.

In 1926, however, it was deemed advisable to start a regular program of painting, designed to keep the bridge in uniformly good condition. In formulating this program, the most careful consideration was given to the method of procedure, equipment, organization, and character of paint, in order to insure the most effective protection to the bridge at minimum cost. The program laid out was made to extend over a period of five years, four years to be utilized in the application of one coat, and the fifth year given over to a detailed inspection of the bridge and the filling of all joints or other places which might allow water to get in and cause corrosion.

The maintenance of such a program, particularly in view of the relatively short season favorable to painting work in the St. Lawrence valley, dictated the use of paint spraying equipment to as large an extent as possible, if it could be proved to be effective and economical, in order to preclude the large force of brush painters which would be necessary otherwise. Extensive tests on the bridge proved the adaptability and effectiveness of spray painting for at least 80 % of the work, and this method was, therefore, adopted.

The first large scale operations with paint spray equipment were started in 1927 after about 25 % of the season's work had been completed, when five two-gun outfits were put in service. These outfits, which are still in use, and have since been supplemented by an additional two-gun outfit, were furnished by the De Vilbiss Company. Each outfit, in addition to the two guns, includes essentially a 14-gallon pressure paint tank equipped with an air-operated agitator, and suitable lengths of air and paint hose. Air for the operation of all of the guns is provided by an Ingersoll-Rand tie tamper compressor, which has a capacity of 160 cubic feet of air per minute.

Little cleaning necessary.

In painting the Quebec bridge, the work is carried across the bridge from one end, taking in both trusses, the floor system and the interior bracing as the work progresses. Cleaning, scraping and spot painting sufficient to keep the full painting equipment busy for about a month is the first work undertaken each year. Upon the completion of this work, the painting is started and brought up with the cleaning work, following which the cleaning work is again carried forward a month or so in advance of the painting work. While cleaning operations are being carried out, the spray painting equipment is thoroughly overhauled and the scaffolding and ropes are carefully gone over and repaired or replaced. When painting operations are resumed, therefore, everything is in readiness.

Owing to the care which has been given to the bridge since its construction and, to a certain extent, to the fact that the deck members are not subject to the attack of any appreciable quantity of brine drippings, relatively little cleaning and scraping work has been necessary, requiring only a week or two of the time of the painting crew, two or three times a season. No scaffolds or power tools are used in this work, the men finding it more convenient and quicker to crawl about over the bridge members and do such cleaning and scraping as may be necessary with wire brushes and simple hand scrapers of different designs. All spot painting is done with brushes, using red lead, and follows closely behind the cleaning.

Extensive use of scaffolding.

Painting of the bridge is done with both the paint spraying equipment and brushes, although the brush work on the bridge is only a relatively small proportion of all of the painting and is confined largely to the interior lattice bracing between the trusses. Regardless of the method of painting, scaffolding is required for the major part of the work, this being of the suspended type, largely with block and tackle hoisting and lowering arrangements to facilitate its adjustment.

The scaffolding used is entirely of timber, made as light as possible, and framed together with, or supplied with, eyebolts to provide convenient and secure hitching points for the supporting ropes. Of necessity the scaffolding assumes many different forms and shapes to serve best in enabling the painters to reach the greatest areas with safety. This factor requires more than ordinary skill on the part of those arranging and hanging the scaffolding and has led to the most careful inspection of all scaffolds before the painters are allowed on them.

Minor adjustments of the scaffolding are made by the painters during painting operations, but all changing of the locations of scaffolds is done by a separate crew of men, which, in fact, keeps scaffolding erected in advance of the painters so as not to delay painting

Fig. 1. — A paint sprayer in use.

operations. The work of the scaffold crew is greatly facilitated and speeded up by the provision of an air-operated winch on the rear of the air compressor car, which is used in all of the heavier hoisting and lowering operations.

Through the skill of the scaffold men

who have been employed on the bridge, and the rigid inspection made of all scaffolding, not a scaffold failure has occurred in the painting work. In fact not a single accident has occurred to any of the painting crew, a record which is most significant in view of the hazards involved.

Spray painting.

In the spray painting work the air compressor stands on the more easterly of the two bridge tracks, which is not used for traffic, and the six-pressure paint containers are scattered about on, above or below the deck in close proximity to the points where actual painting is going on. The men with the spray guns supplied from each tank usually work near each other, and each gun operator is assisted by a helper who holds and insures free movement of the paint and air hose. At many points the helper is not necessary but, ordinarily, his assistance gives a wider range of operation and greater freedom of movement to the gun operator and, incidentally, eliminates the setting up and adjusting of a lot of scaffolding. Frequently, too, the helpers take over the paint guns to relieve the regular painters and, in this way, an excess of capable gun operation is always available.

Fig. 2. — The Quebec bridge. 7 500 gallons of paint are required to give it one coat.

All of the gun operators are equipped with goggles and respirators, but these are generally used only when working in confined areas of where the operators are subject to spray carried by the

wind. One precaution taken consistently by the gun operators to protect their skin and to facilitate cleaning up after work is to coat their hands and face with vaseline before starting work each day.

With a relief operator for each paint gun and the scaffolding kept placed in advance of the work, all 12 guns of the paint spraying equipment are kept busy practically continuously throughout the day. As a further effort to this end,

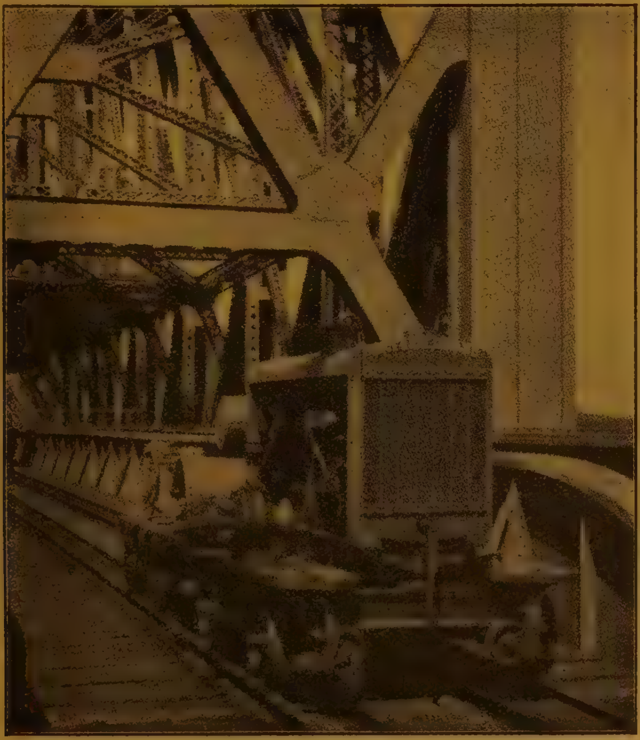


Fig. 3. — The power plant of the painting gang of ihe east portal of the bridge.

filled pressure containers with the paint thoroughly mixed by the mechanical mixers within them, are always kept available to replace those employed in the painting work. These containers are hoisted about the bridge to the points desired by means of the air-operated winch on the platform of the compressor, and thereby, a replenished supply of paint is furnished to the guns with little physical effort and with minimum delay to their operation. Two spare guns are also kept on hand to change out any guns which may give trouble.

Winds, fogs, and mists.

In addition to the hazardous nature of a large part of the work of painting the bridge and the difficulties which this

involves, several other difficulties are encountered in the painting work. Possibly the most important of these are presented by the strong winds which sweep down the St. Lawrence and the frequent heavy fogs or early morning mists which hang over the river valley. Both of these factors increase the hazards of the work and add to the difficulty of securing the best quality of painting.

In many cases, wind of sufficient force to interfere seriously with the most effective use of the paint spraying equipment has made it necessary to shift the work to better protected parts of the bridge, and, in some cases, it has been necessary to give up the use of the paint

Fig. 4. — Working on the deck in windy weather.

Note men wearing respirators—Work on floor girders is done at times when high winds do not permit of painting the more exposed portions of the bridge.

guns entirely. Ordinarily, however, with such broad expanses of steel as are found in many of the bridge members, it is possible to continue work with the spray guns at certain places regardless of wind conditions.

Many of the bridge members and plates are from two feet to ten feet wide and, if sheltered at all, can be painted with little difficulty in a considerable wind. The broad expanses of the through plate girders of the deck system and the interiors of large box members with one or two lattice sides also present surfaces which can be painted effectively when the wind would interfere with painting in fully exposed or unshielded areas. Usually, therefore, painting of these larger members with the guns is reserved for weather less favorable for spray painting the smaller members or those exposed to heavy wind. When it is desirable to curtail the use of the spray guns for a period of time because of

wind conditions, the painters and helpers generally revert to the use of brushes and catch up with the painting of the lattice box members forming the interior bracing system of the bridge.

Fog and mist present the greatest difficulty early in the morning, usually in that they wet the steelwork and necessitate delay in getting started with the painting, sometimes until noon. The fact that all of the bridge members are well ventilated, however, greatly speeds up the drying action of the sun and wind and permits painting much sooner than would be possible if this feature of design had not been incorporated in the bridge design.

In view of the magnitude of the painting operations described and the widespread general interest of the public in viewing and photographing the bridge, the most careful consideration has been given to the quality of paint used and to the general appearance of the bridge structure. Primarily in this latter regard, a paint, olive green in color, is used, which harmonizes most effectively with the surrounding landscape and tends to soften the long bold lines of the steelwork. Widespread favorable comment from the thousands of tourists who visit the bridge each year bespeak the general appreciation and approval of the effort to enhance the appearance of the bridge by the use of the green paint.

A study of the paints best suited to the bridge from the standpoint of durability led to the use of chromate in the pigment as a rust preventive, and resulted in the adoption of the following formula for the pigment as a whole :

	Per cent by weight.
Basic lead sulphate (min.)	54.0
Zinc oxide (min.)	20.0
Chromium oxide (min.)	3.0
Basic lead chromate (min.)	2.0
Lamp black (max.)	0.5
French ochre (approx.)	3.0
Asbestine or other inert material approved	15.0
Total calcium carbonate and calcium sulphate shall not exceed	2.0

The composition of the paint as a whole, by weight, is given in the following.

	Per cent by weight.	
	General painting.	Patching.
Pigment (as above)	58-62	62-66
Raw linseed oil	20-21	18-19
Boiled linseed oil	16-17	14-15
Japan dryer	5	5

Paints of other formulae have been used on the bridge, more or less as tests, the most prominent being one containing a carbonate in the pigment. The greatest satisfaction is being secured from paint of the above formula, however, and it is likely that paint of this character will continue to be used in the future. All paint under the formulae or specifications issued is purchased ready-mixed in five-gallon drums, a manner which has been found most convenient for handling in the work. Not only that, but purchase is made in this size container because of the more thorough mixing that is obtained than when paint is purchased in larger drums or barrels.

Forty men in painting crew.

Owing to the extent of the work of painting the bridge and the limited working season each year, the painting force is maintained at about 40 men, a relatively large force under ordinary circumstances for the operation of 12 paint spray guns. On the other hand, as has been pointed out, there is an unusual amount of auxiliary work in connection with the painting of the bridge, including the brush work and the arranging of scaffolding, which makes necessary a

larger force than would be required ordinarily. In addition, helpers on the deck increase the size of the force, but these men, who replenish the supplies of the painters in addition to carrying out considerable auxiliary work, save a large amount of the time of the painters in climbing back and forth over the bridge in filling their own requirements for materials.

The normal make-up of the painting force on the bridge is as follows :

1 foreman.
1 assistant foreman.
12 painters.
12 painter helpers.
5 men employed in moving and adjusting scaffolding.
3 helpers on the bridge deck, handling supplies.
1 mechanic, who is in charge of the air compressor and who also repairs and regulates the paint spraying equipment.
1 blacksmith, who has charge of the material store and who makes and sharpens all of the scraping tools used on the work, and also makes all scaffold forgings.
2 watchmen, who look after the equipment at night, since it is left out on the bridge continually to save the time and expense of bringing it in to a storage point each night.
1 timekeeper, who keeps the records of the painting force.

In addition, one man is employed as a boatman and is required to row about under that part of the structure where the men are working. The boat is equipped with life preservers for use in case more than one man should fall from the bridge at the same time.

The force as outlined is maintained throughout the working season, altered in arrangement from time to time, depending upon the character of work being done. At the close of the working season, as many of the men are absorbed into the regular maintenance forces of the road as is possible in order to hold them for the bridge painting work of the following year. This applies particularly to the painters, their helpers and the scaffold men, who become more proficient with increased experience in the work on the bridge, and who present much less of an accident hazard than new men.

Spray method shows saving.

In view of the fact that out-of-face painting of the bridge has never been done entirely by the brush method, it is impossible to compare by actual figures the cost of the spray painting work with that of brush painting. Neither is it possible to state accurately the size of the brush painting force that would be necessary to accomplish an amount of work equivalent to that effected by the spray painting force of 40 men. Such comparable data as are available, however, indicate that a force employing the brush painting method exclusively would have to be three or four times as large as the spraying force, and that the cost of work would be increased materially.

An analysis of the cost of the painting work carried out during 1927, in which year 10 paint guns were put in operation after about 25 % of the season's work had been done by the brush method, shows that the labor cost of applying the paint amounted to $7.14 per gallon, this including all auxiliary items such as scraping and spot painting. In 1928, in which year the spray painting method was used exclusively, except in painting the inside bracing, the labor cost of the spray painting alone amounted to $2.83 a gallon, while the total cost of painting, including all items except the cost of the paint, was $5.34 a gallon of paint applied to the bridge.

Amount of paint applied.

Records of the complete four-year painting program, from 1926 through 1929, show how the paint spraying equipment has increased the amount of work accomplished. In 1926, with a large brush painting force, 1 762 gallons of paint were applied. In 1927, owing to the curtailment of the painting program, only 896 gallons of paint were applied, in spite of the fact that 10 paint spray guns were put in operation that year after about 25 % of the work had been completed. In 1928, with the same paint spraying equipment, 2 073 gallons of paint were applied to the bridge, and in 1929, with 12 spray guns in operation; 2 765 gallons of paint were applied, completing the single-coat painting of the bridge, which, altogether, involved the application of 7 496 gallons of paint.

The quality of the work which has been done with the spraying equipment is said to be excellent. It is admitted that there is some loss of paint in using this method, particularly when working on small members unprotected from the wind, but it is felt that this loss is small and that it is more than compensated for by the speed and economy with which the paint is applied.

The painting of the Quebec bridge is done under the general direction of T. T. Irving, chief engineer, and C. P. Disney, bridge engineer, Central region of the Canadian National, and under the direct supervision of E. S. Piton, bridge and building master.

[625 .258 (.42)]

A new rail brake.

Figs. 1 and 2, pp. 943 to 945.

(*The Engineer.*)

The latest development in hump yard operation is the eddy current brake made by the Westinghouse Brake and Saxby Signal Company, Ltd., of 82, York-road, King's Cross, London. That a braking effect can be produced by eddy currents in a metal disc revolving in a magnetic field has been known for many years, but the possibility of utilising this eddy current effect for the purpose of retarding railway wagons was first realised by Drs. Baeseler and Thomas, who, in 1925, produced an eddy current rail brake which was shown at the Transport Exhibition held in Munich in that year. Subsequent experiments led to the design of another eddy current brake, which was installed at Magdeburg in November, 1928, and this brake has been in operation day and night ever since. From tests carried out on the brake while in actual operation, useful information was obtained, and as the result of this the improved brake, which is being supplied by the Westinghouse Brake and Saxby Signal Company, and which was demonstrated at the company's Chippenham works on Tuesday, 24th March, was evolved. A plan of, and cross sections through, a double rail brake are shown in figure 1, from which it will be seen that brake beams A extend through the whole length of the retarder and are supported at intervals by core pieces B, which rest on the cores C of electro-magnets. The beams A are capable of limited movement towards, or away from, the running rails, this being made possible by hinges E, whilst springs F constrain the movement and return the beams to their normal position when the brake is unoccupied. Foundation bolts hold the magnet rigidly on the concrete foundations. The poles between which the wagon wheels run, consist of bars G, which normally project above the beams A, and as a certain amount of wear on the parts actually in contact with the wheels is inevitable, separate wearing strips H are attached to the bars G in order to make replacement as simple and inexpensive as possible. If it were not necessary for locomotives to pass through the brake, the bars G might be rigidly fixed to the beams A, but as locomotives might foul the bars in this position, provision has been made for lowering the bars into a position in which their tops are on a level with the upper surface of the beams A. For this purpose the mechanism shown in the upper part of figure 1 is provided. At intervals the bars are attached to blocks, which slide in sloping guides J, fixed to the brake beams A, and raising or lowering is effected by pushing or pulling the bars horizontally by means of a rod K, operated by a motor L through gears and the screwed shaft M.

This is the only mechanically operated part of the brake, the actual moving parts being the bars G, and as this movement plays no part in the braking action, the process of braking may be said to be achieved without any move-

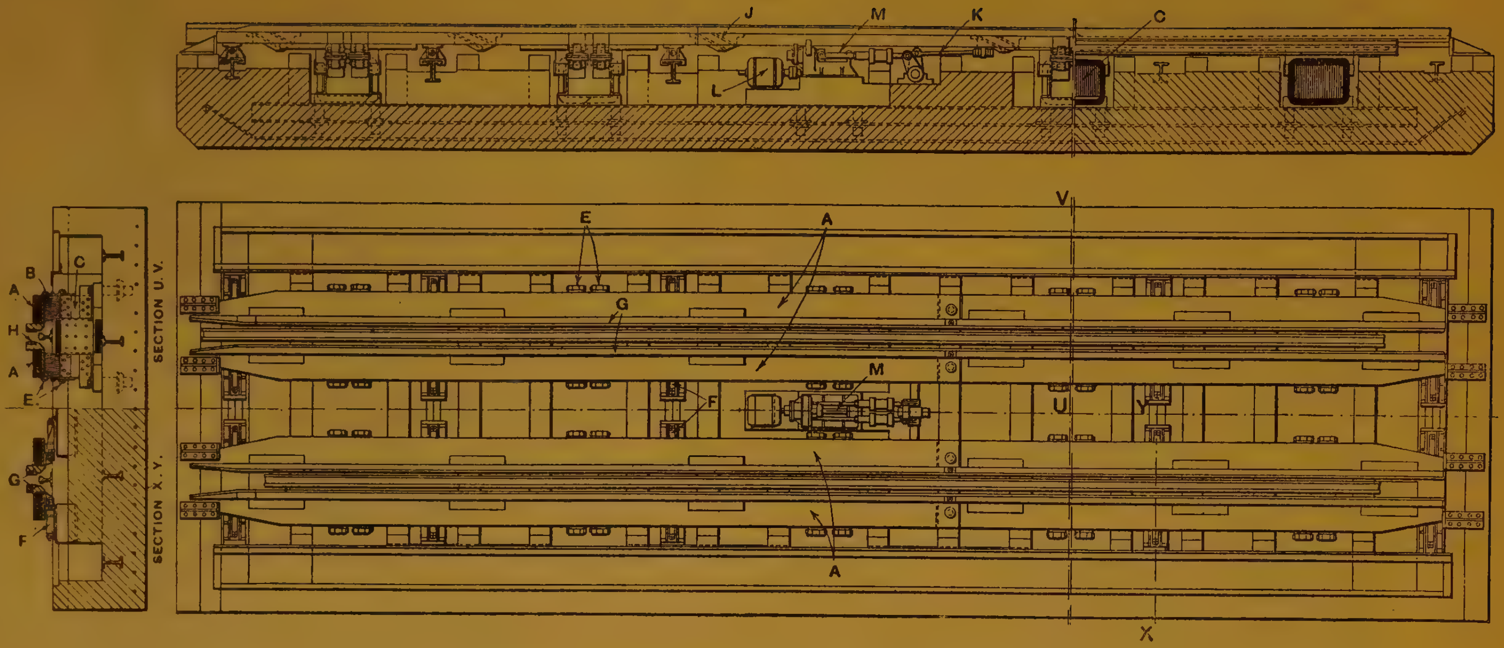


Fig. 1. — Plan and sections of double rail eddy current brake.

ment of the parts other than the brake beams A in adjusting themselves to the slightly varying thickness of the wheel tires. The overall length of the standard retarder is 50 feet, and a double retarder of this length is fitted with twelve magnets, or six per rail. As shown in the drawing figure 1, the magnets are mounted horizontally immediately beneath the rail, the windings being impregnated and enclosed in a sealed sheet metal case, with sealing compound, which renders the whole structure absolutely water-tight and failure as the result of the track becoming flooded is not, therefore, likely to be experienced. Channels are provided in the reinforced concrete foundation for the purpose of drainage and for laying the cable. The magnet cores and the brake beams A are composed of sheets of steel, which are riveted together, while the core pieces connecting them consist of plates loosely held together and hinged to both the brake beams and the magnet cores in the manner described. This loose construction permits of the movement of the brake beams necessary to allow for varying wheel tire thicknesses, while, owing to the attractive and binding action of the magnetic field produced, which holds the plates firmly together, no rattling and consequent wear can occur during operation. If desired, the brake can be mounted on a wooden foundation, which besides being cheaper than concrete, can, if the necessary preparations are made beforehand, be put into place during a slack period. The foundation is laid on about 10 inches to 1 foot of ballast and consists of a framework of sleepers lying close together. On this framework stout oak baulks are laid lengthwise and they carry the sleepers for the track rails, the poles of the magnets being fastened by special wooden supports to the longitudinal baulks.

When the magnet windings are energised before the wagon wheels enter the brake, a magnetic flux is set up round the cores, through the core pieces, and across the gap, and tends to draw the brake beams together. The springs F, however, restrain the moment of the beams, and it is only when the wagon enters the brake that the magnetic circuit is completed through the wheel tires. Owing to the change of reluctance brought about by the introduction of the magnetic material of the wheel tire, there is a tendency for a great and sudden increase of the flux, but, owing to the rotation of the wheels, this is opposed by the setting up of eddy currents in the tires and brake beams and it is the interaction of these eddy currents and the magnetic flux that produces the braking effect. When the wheels enter the brake, on account of the great magnetic attraction, they are gripped by the brake beams, and a certain amount of friction occurs. A portion of the braking effect is, therefore, purely mechanical, but it is only in the neighbourhood of about 20 to 30 % of the total effect. In consequence of the fact that when the wagon enters the brake the building up of the flux is delayed, the wagon always enters the brake perfectly smoothly, irrespective of its speed or weight. The strong magnetic field passing through the wheel tire tends to bind the wheels to the brake and to hold the wagon down on to the track. The greater the amount of energy applied to the brake, the more pronounced does this effect become, and it is said that the lightest wagons may be run into the brake at the highest speed without fear of derailment.

The brake need not always conform with the arrangement shown in figure 1. It is not necessary, for instance, to have a brake acting along both rails. Single-rail brakes are sometimes advantageous and the eddy current brake is particularly applicable to a single rail, as no resultant torque is set up on the wagon axles, as is the case with single-rail fric-

tion brakes. The electro-magnets are wound for a d. c. pressure of 440 volts, the maximum load current being about 160 amperes. If a 440-volt d. c. supply be available, the brake can be fed direct from the mains through series resistances for control purposes, while if the supply is a. c. the brake can be fed by a motor generator set or through rectifiers, and as the magnets are only energised for very short periods, full advantage can be taken of the overload

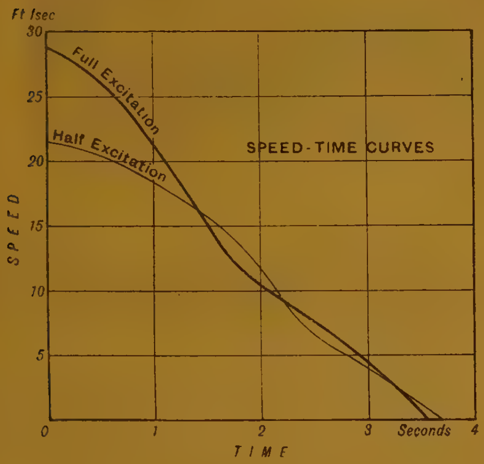


Fig. 2.

capacity of the converting plant. Two or more definite values of excitation are provided for, and even the lightest wagons can be subjected to the maximum retaining effort without danger. Provision is made for breaking the highly inductive circuit as rapidly as possible.

For controlling purposes a very simple arrangement is provided, there being two buttons for starting and stopping the motor generator set, and a control handle for the brake. Adequate protection is provided to ensure against faults at the brake and other apparatus, and mistakes on the part of the operator. In the case of an overload occurring at the brake, a lamp lights up and a bell rings outside the control cabin.

The retarder control handles, the point-thumb switches, the hump signal control, and indication lamps are mounted on a sloping panel of the control desk, which is arranged so that the operator may sit before it with an unobstructed view of the territory over which he has control. The panel may be provided with a schematic track diagram of the yard, and in this case the point-thumb switches would be situated at appropriate parts of the diagram, and there would be three indication lamps for each set of points.

At the summit of the hump there is a humping signal of the three-aspect colour light type, controlled on the « series indication » system, which repeats the actual signal on the control panel and also provides for the dual control of the signal by the operator and the head shunter.

The retarder is claimed to possess a number of important advantages over those depending purely on mechanical friction. The danger of derailment of wagons through the squeezing of the brake beams is a matter which has engaged the attention of many brake designers, and has often been a source of trouble to users, but with the eddy current brake, no trouble occurs. This, we are told, has been amply proved by tests carried out on the brake when light empty wagons were run into the fully excited brake at the highest speed obtainable, and in spite of the very rapid retardation no trace of lifting was observed. Tests are also said to show that the braking effort obtained is just as powerful as that of friction retarders, whilst on account of the very smooth entry of wagons into the retarder there is no danger of damage being done to the loading. As the braking force due to friction is small in comparison with the total force, the performance of the brake is very constant, and weather con-

ditions, the presence of grease, roughness of the wheel surfaces, and other factors which interfere with friction braking have little effect. The freedom from moving parts, the makers point out, is an important advantage, especially where severe weather conditions are experienced. The saving in inspection and maintenance is very appreciable, for whereas the moving parts of mechanical brakes wear, and require replacement, the life of the corresponding heavy parts of the electric brake is only determined by rusting and corrosion. The vertical raising of the brake beams, which is necessary to allow locomotives to run through the retarder unhindered, is a feature of many forms of brakes, but in the present case this movement has been limited to the actual brake bars, the remainder of the equipment resting firmly on the foundation, thus promoting rigidity and ruggedness of construction.

The possibility of certain goods such as watches and clocks being injured as the result of the strong magnetic field may appear to be a disadvantage, but it seems that this possibility was realised by the German State Railway Authorities, who carried out tests on the brake installed in the Magdeburg yard, where it was found that at a height of 3 feet above the rail level the magnetic field did not damage the most delicate articles. The curves shown in figure 2 are typical speed-time curves taken on wagons brought to rest by this form of brake, the curve for full excitation naturally being steeper than that for half excitation.

[625. 258 (73)]

The Erie Railroad installs retarders in Marion yard.

Figs. 1 to 3, pp. 947 and 948.

(*Railway Age.*)

The Erie has recently completed the installation of car retarders and power switch machines in its reconstructed westbound classification yard at Marion, Ohio. As a result of these improvements, the operating cost of handling cars through the yard has been reduced approximately 40 cents per car, and the capacity of the yard has been increased to such an extent that classification formerly handled at other yards is now being done in Marion.

Operating problems.

Marion is located 269 miles east of Chicago on the main line of the Erie from which point a branch line extends 144 miles southwest through Dayton, to Cincinnati. The St. Louis, Mo.-Cleveland, Ohio, main line of the Big Four connects with the Erie at Marion and operates jointly with it for 21 miles to Galion, Ohio. Within the limits of the interlocking at Marion Junction, the Erie is also crossed by the Toledo main line of the Chesapeake & Ohio, and the Sandusky-Columbus line of the Pennsylvania.

When coal traffic is moving, the Erie receives from 500 to 600 cars from these connections daily. In addition to this coal, the westbound traffic classified at Marion includes merchandise and manufactured products from the east, and

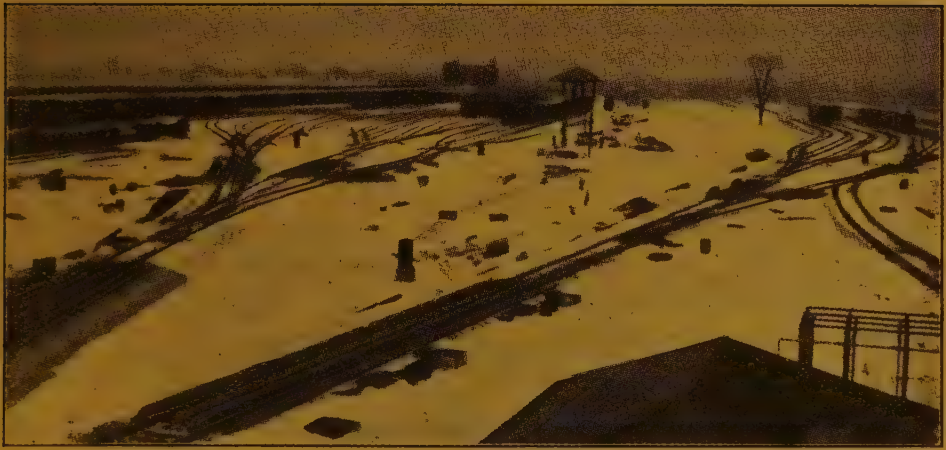


Fig. 1. — The old yard is a the left and the new at the right.

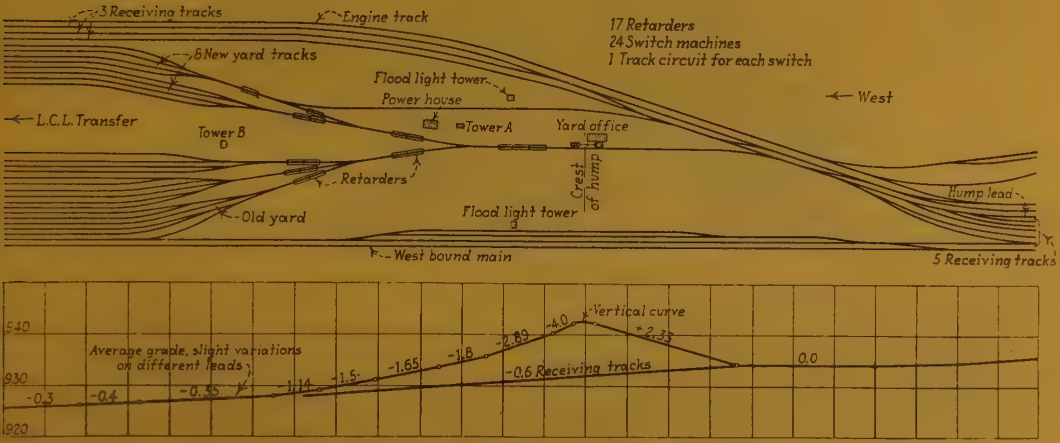


Fig. 2. — Plan of yard layout showing grades.

numerous empty refrigerator cars for fruit and meat service.

The westbound classification facilities at Marion were improved in order that complete classifications could be made for connecting lines west of Marion and for the Chicago gateway, as well as for certain industrial districts and freight stations on the Erie in Chicago. Thirty separate classifications are now being made in the new layout with 24 yard tracks. Approximately 3 000 westbound cars can be classified daily, as compared with a maximum of 1 629 cars under the old system of rider operation in vogue a year ago.

Yard improvements.

The old westbound yard included 16 tracks lying in a general east-and-west direction north of the main line. An l.c.l. freight transfer station was located just north of this old yard, and although it is planned to move these facilities elsewhere within the next few years, it was not necessary to do so in order to enlarge the yard, because the eight new tracks were located north of the l.c.l. transfer. Therefore, this arrangement leaves space for 12 additional tracks when the freight transfer is relocated.

The limitations occasioned by the location of the enginehouse and highways did not allow space for the construction of an adequate receiving yard east of the hump. Therefore, as a means of getting out of the way a westbound train that arrives when another train is being humped, a three-track receiving yard was constructed alongside and

Fig. 3. — A four-track group in the new side of the yard.

north of the classification yard. This arrangement has occasioned no serious inconvenience.

The new arrangement necessitated that the hump be relocated near the center of the enlarged track layout. New leads were built from the new hump to connect with the 16 tracks in the old yard and the 8 tracks in the new addition. The capacity of the tracks varies from 39 to 125 cars, with a total yard capacity on the classification tracks of 2 000 cars. The natural slope of the ground in this area is westward, and a fill varying from 3 to 13 feet required approximately 76 000 cubic yards of clay, with a top dressing of cinders. New 110-lb. rails with treated ties and crushed rock-ballast were used down the hump and throughout the retarders and switches, while 100-lb. relayer rails with gravel ballast were used on the yard tracks.

In designing the grades down the hump and throughout the yard tracks, consideration was given to the fact that many empty cars were to be classified. The climatic conditions and the fact that the prevailing wind is from the southwest also entered into consider-

ation. As shown on the diagram, the grades on the hump range from 4.0 to 1.65 %, gradually reducing to a non-accelerating grade of 0.3 % on the tangent yard tracks beyond the switch leads.

The leads in the old yard were arranged on the V-ladder principle, whereas those in the new layout are in five groups of from four to six tracks each. Each group is served by one double retarder, while seven more retarders are located in three groups on the main leads and hump, as shown on the diagram. This grouping of the tracks reduced the number of retarders required to a total of 17, and, in addition, gives quicker separation of cars destined to the different tracks, thus speeding up the operation of the yard.

The 24 classification switches are power-operated, and track circuits and detector locking are employed to prevent a switch from operating under a car. Each track circuit extends a minimum of 20 feet in the approach to the switch points, and 34 feet back of the point. The switches, together with the retarders are controlled from two towers, with one operator in tower A and two in tower B. Teletype equipment is provided for making switching lists in the yard office and in each of the towers.

The retarders and power switches are of the electro-pneumatic type, and together with the signals, were installed by the Union Switch & Signal Company. The model-28 car retarder used in this yard provides automatically for car wheels to drop back on the rails if they should inadvertently be pinched out of the retarder.

Improvements in yard operation.

With the operation in the old yard, a crew, consisting of a conductor, 12 riders and 3 switch tenders, was employed to handle, 1 200 or more cars daily, the maximum being 1 629 cars. While the yard costs are not separated as between westbound and eastbound yards, the records show that the operating costs were about 94 cents per car a year ago when an average of 2 300 cars were handled daily in both east and westbound yards, which compares favorably with the traffic now being handled. The eastbound yard is operated by yard brakemen and car riders as before, the only improvement in layout or equipment being in the westbound yard. However, certain economies have been accomplished by improved methods of operation in the yard as a whole during the year.

As a result of these improvements in yard layout, equipment, and methods of operation, it has been possible to reduce the number of yard engines required; where 28 daily were required a year ago, the number now ranges from 11 to 18. Additional economies, including the reduced cost of operating the westbound yard, now equipped with retarders, has reduced the average operating cost for yard service from 94 cents a year ago, to 50 cents per car classified in both yards, and operating officers estimate that about 32 cents of the saving per car has been brought about by the new westbound yard layout and retarder equipment.

The yard improvements cost $597 000, including $240 000 for the retarders, power switches, signals, compressor equipment, teletype system, floodlighting layouts, etc. On the basis of the present number of cars handled, an annual saving of approximately $175 000 is made, which represents a return of approximately 30 % on the investment. Furthermore, as explained previously, the operating expense will be increased so slightly that the cost per car will be decreased rapidly as traffic grows and as the classifications now made at Hammond, Ind., are transferred to Marion.

[621.87 (.42)]

A railway breakdown crane of 105 tons capacity.

Figs. 1 and 2, pp. 951 and 953.

(*The Railway Gazette*)

There has recently been completed at the Ipswich Works of Ransomes & Rapier the most powerful railway breakdown crane yet built in Great Britain, with a lifting capacity of 105 tons. In any high-capacity crane of this character, one of the chief problems to be solved is that connected with its mobility. It must pass within the loading gauge of the railway over which it is used, and it must also, when in travelling order, conform to the usual restrictions on maximum axle-loading of rolling-stock. It is to meet the latter restrictions that the Stokes principle of the relieving bogie has been evolved. The crane, when running, is flanked at both ends by bogie trucks of special design, to which part of its weight is transferred, and this has the effect of distributing the weight over a considerably longer wheelbase; but when the crane reaches the site of operations, the bogies can be uncoupled and removed in a few minutes, and the crane then works on its own suitably short wheelbase when dealing with heavy loads. By means of a screw and worm-wheel arrangement, each of the bogies is permanently attached to one end of a coupling member or relieving girder, about which the bogie itself is free to swivel. The method of attachment of these relieving girders to the headstock of the crane is such, again, that swivelling motion is possible. The fixed wheelbase of the crane is thus in no way increased when it is in running order, but the set of three vehicles has a degree of flexibility which enables them to traverse with ease the sharpest curves in any ordinary railway track. Suitable indicators are provided on the bogies to enable an operator with but limited experience to prepare the crane for the road or for lifting, and with the crane under review, the work of coupling and uncoupling the bogies and transferring the load is accomplished without difficulty in from 3 to 5 minutes.

There are other advantages attaching to the Stokes principle. With a breakdown crane of the ordinary type, the match-truck provided to run with the crane, in order to clear the full length of the jib in the horizontal running position, may be anything up to 35 feet in length. On arrival at the wreck, or whatever the particular work may be, the crane has first to dispose of the match-truck, and unless it is left some distance away from the site of operations, this is sometimes a matter of no small difficulty, owing to the probable inability of the crane to swing so large a vehicle round on its own rail from a leading to a trailing position. With the Stokes crane, however, a short match-truck is sufficient to afford the necessary clearance for the end of the jib. Thus it is possible to move this type of crane right up to the work before the bogies and match-truck are removed — a point of no small importance, as it preserves the moderate axle-loading of the crane (in running order) over track which may be damaged as a result of the wreck, and so in an unsuitable con-

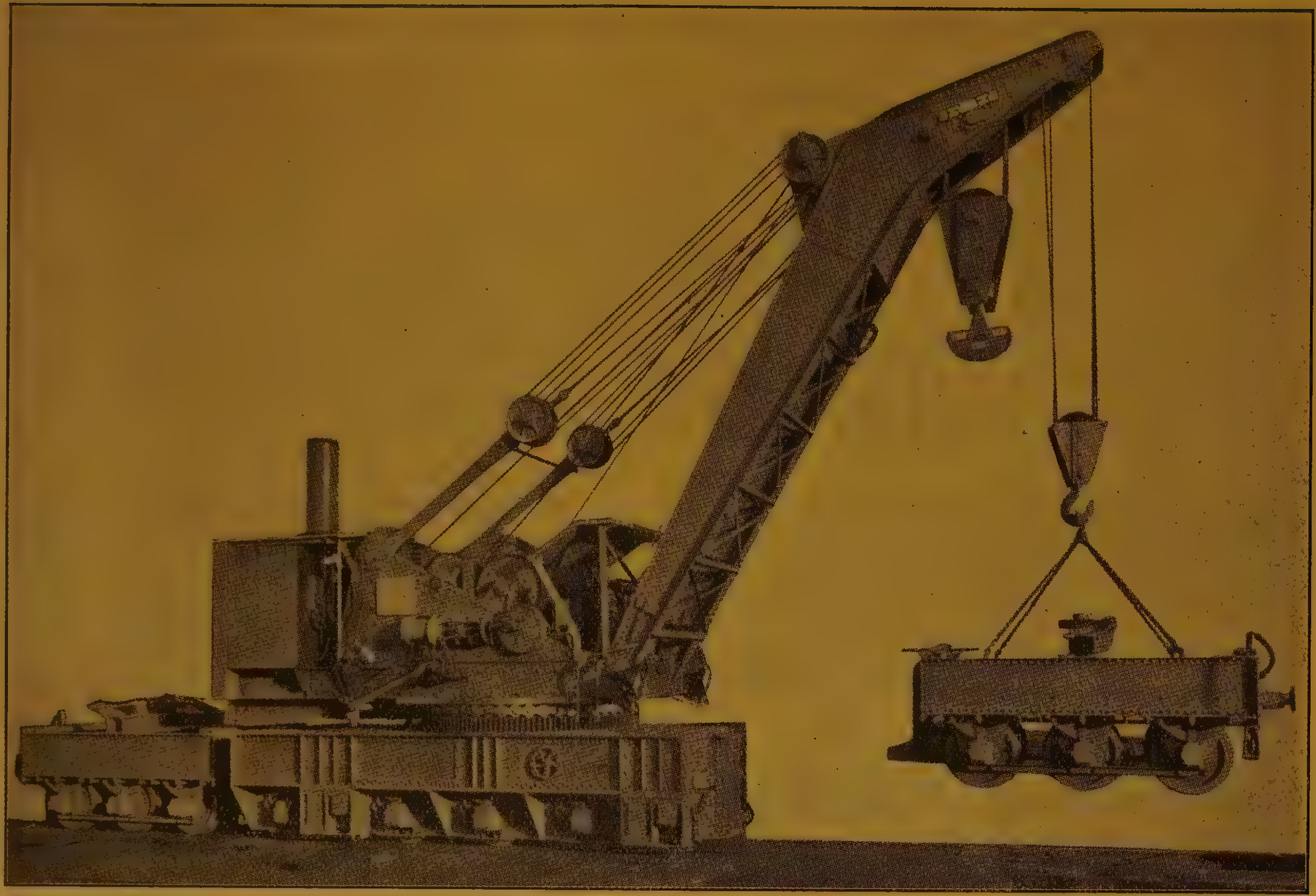


Fig. 1. — General view.

dition for carrying any abnormal loads. In the setting of bridge girders, also, this property is of considerable value.

Again, with the ordinary type of heavy breakdown crane, if, in order to give equal clearance of the jib over both ends and an even axle-loading, the revolving superstructure of the crane be arranged with its axis central between the headstocks, when in running order, it is necessary to suspend the jib by means of the derrick ropes; were the jib rested on the match-truck, the tail-weight would throw too great a load on the axles at one end of the crane carriage. This undesirable arrangement can be avoided only by placing the crane axis forward of the centre of its carriage, but this, on the other hand, reduces the clearance over the rear headstock, so that, if full use is to be made of the crane on arrival at its work, it is imperative that it shall arrive with the front headstock leading. It is this reduction of rear clearance that often prevents the crane from placing its own match-truck on the rail behind it, as mentioned in the last paragraph. But with the Stokes arrangement, a short crane carriage of robust construction can be employed, with the crane axis symmetrically located on the centre of it, giving equal clearance over each headstock and a maximum clearance at that, after the removal of the relieving bogies. This is of great importance in the lifting of bulky loads. Also it permits of part of the weight of the jib being carried by the match-truck, so further distributing the weight of the crane when in running order. The short rigid wheelbase of the Stokes crane can be made flexible, if desired, by the substitution of two four-wheeled bogies for the four rigid axles, making the crane suitable for travelling over exceptionnally sharp curves. In the particular crane under review, however, fixed axles are employed.

The duty for which this 105-ton crane has been designed is as follows :

Lift with outriggers.

Main hook	105	tons at	20 feet	radius with full ballast.
— —	65	—	25 feet	— — —
— —	45	—	30 feet	— — —
— —	90	—	20 feet	radius with removable ballast detached.
— —	60	—	25 feet	— — — —
— —	40	—	30 feet	— — — —
Auxiliary hook	25	—	35 feet	— — — —

Lift unpropped.

Main hook	20	tons at	20 feet	radius.
Auxiliary hook	15	—	25 feet	—
— —	12	—	30 feet	—
— —	8	—	35 feet	—

Under test, the crane lifted a maximum load of 126 tons; the normal carrying capacity of 105 tons would be more than sufficient to lift one of the Gresley *Pacific* locomotives of the London & North Eastern Railway. The maximum height of lift at 20 feet radius is 24 feet above rail level, and the maximum depth to which the crane is able to lower is 16 feet below rail. At the maximum full-load radius of 20 feet there still remains a clearance of 9 ft. 6 in. from the front of the headstock to the vertical line of lift. As regards speed, the crane under test lifted, by means of the main hook, 105 tons at 10 feet per

minute, and 50 tons at 20 feet per minute; while the auxiliary hook lifted 25 tons at 55 feet per minute. Derricking was accomplished with full load at 5 feet per minute, and slewing at one-quarter revolution of the crane per minute; the rate of travel of the crane in slow gear was 75 feet per minute and in fast gear 6 m. p. h.

Attention may now be devoted to the leading constructional details. The jib is of the swan-neck type, with plate sides, braced at the top and the bottom. Double plating with packers for the bearings and engine fixings is employed for the crane sides, making a particularly stiff and solid framework, to which the tail girders are firmly attached and support the boiler and the ballast. The permanent ballast consists of vertical slabs at the extreme rear of the crane, through which suitable openings have been cut to give access to the boiler manhole and the tube doors. For the heaviest lifting operations, arrangements are made to carry additional removable ballast; the crane attaches this by lifting the slabs on to its carriage, and then slewing its superstructure until the tail is immediately over the ballast, which is then easily attached. In this way it is not necessary for another crane to be employed for the purpose of adding the removable ballast. Propping girders are provided to enable the crane to take a firm bearing on the ground, at the maximum possible distance from the centre-line, as well as the bearing on the track. These are built up of rolled steel sections, and are of a telescopic type, in two sets, one at the front and the other at the rear of the crane carriage; rack-and-pinion gear operated by ratchet handles is fitted, so that the girders may easily be run in and out of the boxes containing them. Usually, with the Stokes type of crane, these boxes form rigid headstocks for the carriage, but in this crane only the forward box forms the headstock, the rear box being placed

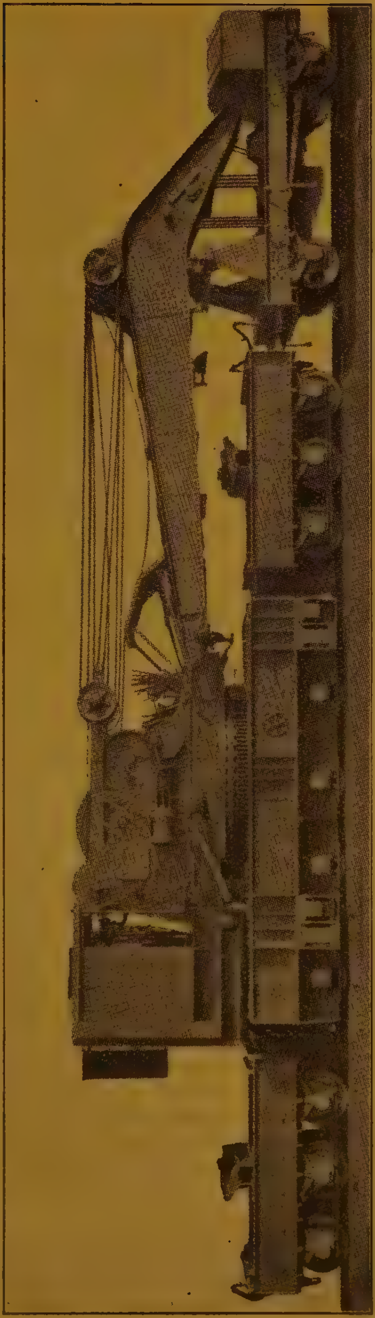


Fig. 2. — General view of breakdown crane in running order.

between two of the axles. The end of each propping beam is arranged to be attached to an equalising beam fitted with two propping screws, so that a perfectly even bearing may be obtained on uneven ground; the maximum width of bearing thus obtained, when the beams are fully extended, is 17 feet, or more than three times the width of the gauge on which the crane itself stands. The carriage is built up of rolled steel sections, strongly diaphragmed and riveted together, while the top foundation, to which the crane sides and all brackets are attached, and which thus forms the foundation of the superstructure, is of cast steel. Each axle of the carriage is separately sprung, and relieving screws are fitted in order to avoid damage to the springs when the crane is working.

The boiler, 5 ft. 6 in. diameter and 8 ft. 6 in. high, is of the Cochran-Hopwood multi-tubular type, supplied by Cochran & Co. Ltd., of Annan, and has the usual equipment. The working pressure is 150 lb. per square inch. The cylinders, two in number, are of 11 inches diameter by 12 inches stroke, and are cast with their guides in one piece; metallic packing is employed for piston and valve-rods; and cylinder lubrication is by means of forced feed into the main steam-pipe. The engine exhaust can be turned into the chimney, for purposes of draught when required, or into the atmosphere at will. Steel gearing with machine-cut teeth is employed throughout, with the exception of the slewing rack-and-pinion, and travel spur-gear, which have cast-steel teeth. The travel gear is operated by a shaft down the centre pin, operating two of the four axles, and the spur wheels on the axles are arranged to slide, so that when the crane is in train order the gears are out of mesh. The spur wheels are engaged or disengaged by means of handwheels on the side of the carriage. Brake gear is fitted to two of the axles, and can be operated either by hand wheels, one on either side of the carriage, or by a steam cylinder fitted on the superstructure and controlled by the driver in his working position. To obtain creeping speeds when dealing with heavy loads, a special type of oil-brake has been designed, on the principe of a reversed oil pump, which is capable of being engaged with the crank disc, and on test gave a speed no greater than 3/4 inch per minute when the crane was handling a load of 105 tons. It is possible to adjust this brake in such a way as to give faster or slower speeds as desired. A point of special note about this crane is the exceptional view obtained by the driver, all of whose controls are assembled in the fore part of the superstructure; in consequence of this arrangement, a separate fireman is required, but this provision would have been necessary in any case with a crane of this size. A canopy, which can be collapsed when the crane is running in train order, is placed over the driver's position, and further protection is afforded by removable canvas side-covers. A fixed canopy is also arranged over the boiler and the fireman's position. The length of the crane carriage is 25 ft. 6 in.; the maximum height above rail, in running trim, is 15 ft. 9 in., and the maximum width 10 ft. 2 in. Such dimensions would, of course, preclude it from running over a British railway, though there would be ample clearance on the 4 ft.-8 1/2 in. gauge lines of Canada, the United States, the Argentine, the Australian States which employ this gauge, and elsewhere. The tail radius is 15 ft. 9 in. A curve of 300 feet minimum radius can be traversed.

The frames of the Stokes relieving bogies are built up from rolled-steel sections. A ball-and-socket connection is provided between each relieving girder and its bogie, allowing for motion in all directions of the one relatively to the

other, and worm-and-screw gear is arranged for adjusting the weight on the bogie, with gauges giving a clear indication as to when the adjustment is correct. At the crane end, each relieving girder is provided with two tongues, which fit into sockets on the crane headstock, making a rigid connection in the vertical plane, but allowing of flexibility in the horizontal plane. The match-truck has no special features, except that the buffers are hinged in such a way that it is possible to house them into the headstocks for the purpose of reducing the overall length of crane, bogies and match-truck to 75 feet; this was a special requirement of the purchasers. The aggregate weight of the four vehicles is 177 tons, of which the crane itself is responsible for 143 tons, the front and rear bogies for 11 tons each, and the match-truck for 12 tons. In running trim the match-truck, carrying part of the weight of the jib, weighs 21 tons; the front bogie, carrying 29 tons of the crane weight, totals 40 tons; the weight of the crane itself is reduced from 143 to 67 tons — that is, less than halved — while the rear bogie, with 38 tons of the crane weight, turns the scale at 49 tons. In this order the axle-loadings, successively from front to rear, are 8 and 13 tons; 13, 13 and 14 tons; 16 1/2, 17, 17 and 16 1/2 tons; and 17, 16 and 16 tons; the maximum load on any one axle is thus 17 tons. In addition to these weights, the crane is provided with 11 tons of removable ballast. The length of the crane carriage is 25 ft. 6 in.; over the two bogies the length is 55 ft. 7 in., and crane, bogies and match-truck together measure 76 ft. 4 in. overall.

A special feature of the crane equipment is that of self-contained electric floodlighting. A turbo-generator set of 550 watts capacity, supplied by J. Stone & Co. Ltd., of Deptford, is carried on the revolving superstructure of the crane, and supplies current at 32 volts to 150-watt « Tonum » floodlights on the jib and on both sides of the crane, as well as to suitable lighting inside the cab. Collector gear is also fitted to supply four sockets, one at each corner of the carriage, for the purpose of plugging in portable floodlights. In conclusion, it may be added that the crane has passed successfully through exacting tests, some of which, by the courtesy of the makers, we have been able to witness, and has proved itself more than capable of fulfilling every requirement of the specification to which it has been built.

[313 : 625 .143.3]

Statistics of rail breakages for the year 1930.[1]

(*First part.*)

We publish hereafter, in the new form adopted at the Madrid Congress (1930) [1], the information supplied by our member Administrations with regard to the rail breakages which occurred on their systems during the year 1930.

Some Administrations having been unable to draw up statistics in this new form, in time for present publication, have sent in information as required by the previous resolutions of the London Congres (1925) [2], at the same time intimating their intention to draw up their statistics for 1931 according to the requirements of the Madrid Congress.

In the tables hereafter, and unless otherwise stated :

Light rails *applies to rails of a weight less than 85 lb. per yard (42.5 kgr. per metre).*

Medium rails, *to rails of 85 to 105 lb. per yard (42.5 to 52.5 kgr. per metre).*

Heavy rails, *to those weighing 106 lb. per yard (53 kgr. per metre) or over.*

GERMANY.

Deutsche Reichsbahn-Gesellschaft.

Our statistics of rail breakages, as kept up to now, do not enable us to fill in the table submitted; we have, however, decided to extend our statistics in the sense indicated.

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(1) See *Bulletin of the Railway Congress,* December 1930 number, pp. 2236, 2240-2242.

(2) See *Bulletin of the Railway Congress,* March 1926 number, p. 240.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ARGENTINE Buenos-Ayres Great Southern Railway (1)		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels { *Light* . .	1	119	5.2	...	73	...	...	17	...	...	102	...	47	1 101	26.7	48	1 415	21.2	17
Medium .	4	551	4.55	1	218	2.87	1	114	5.5	8	1 630	3.16	2	1 377	0.9	16	3 890	2.57	19
Total. . .	5	670	4.6	1	291	2.15	1	131	4.8	8	1 732	2.9	49	2 478	12.36	64	5 305	7.54	

Number of train-miles: 15 081 380.

Number of English ton-miles: 1 735 529 000.

Number of fractures { total: 64. per 10 000 000 train-km. or 6 250 000 train-miles: 26.5. per 1 000 000 000 tonne-kilometres or 612 000 000 English ton-miles: 22.5.

(1) Incorporating « Bahia Blanca North Western ».

	Percentage of fractures in the part covered by the fishplates	Percentage of fractures in the part clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	on curves of ⩽ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ⩽ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Medium rails* . .	44 %	56 %	64	...	...	64	...
		Total . . .	64	...	...	64	...

E. — *a*), *b*) and *c*): No data.
d) Number of pieces rails are broken into: 2.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cordoba Central Railway.											Miles.			Miles.			Miles.		English tons.
Rails outside tunnels. } *Light* . .	...	...	...	...	...	...	...	...	...	8	558	8.96	299	1 473	12.68	307	1 473	13.02	16

Note. — Records regarding the relative position of breaks to the fishplates, radius of curve on which these took place, and condition of fractures have not been kept in detail.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS : Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Buenos Ayres and Pacific Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels: *Light* . .	...	...	...	...	...	...	...	...	...	5	1 122.6	2.78	33	1 122.6	18.37	38	1 122.6	21.04	13-19
Medium .	2	1 917.7	0.65	1	1 917.7	0.32	...	...	...	2	1 917.7	0.65	11	1 917.7	3.59	16	1 917.7	5.18	19-21.6
Heavy. .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total. . .	2	1 917 7	0.65	1	1 917.7	0 32	...	...	...	7	3 040 3	1.44	44	3 040.3	9.05	54	3 040.3	11.10	

Number of train miles : 8 894 188.

Number of English ton-miles : 1 438 158 335.

Number of fractures:
- Total : 54.
- Per 10 000 000 train-kilometres or 6 250 000 train-miles : 37.72.
- Per 1 billion tonne-kilometres or 612 000 000 English ton-miles : 23.15.

	Percentage of fractures in the part: covered by the fishplates	Percentage of fractures in the part: clear of the fishplates	NUMBER OF FRACTURES : on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails* . .	9	29	8	No data.		30	...
Medium rails .	5	11	2	...		14	...
		Total. . .	10	...		44	...
	Miles of single track of each class . .		No data.				

E. — *a*), *b*), *c*) and *d*) : No data.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Buenos Ayres Western Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels *Light*	2	45.4	28	...	1.8	...	...	1.8	...	...	44.5	...	40	1 559.9	16	42	1 653.4	17	19
Medium	7	43.5	100	4	52.8	47	...	59.0	...	1	236.1	3	3	15.5	120	15	406.9	23	19
Total	9	88.9	63	4	54.6	45	...	60.8	...	1	280.6	2.2	43	1 575.4	17	57	2 060.3	18	
B. Rails in tunnels *Light*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Medium	2	1.2	1 050	...	...	...	...	...	...	...	...	...	...	...	...	2	1.2	1 050	
Total	2	1.2	1 050	...	...	...	...	...	...	...	...	...	...	...	...	2	1.2	1 050	
C. The whole of A and B *Light*	2	45.4	28	...	1.8	...	...	1.8	...	...	44.5	...	40	1 559.9	16	42	1 653.4	17	
Medium	9	44.7	126	4	52.8	47	...	59.0	...	1	236.1	3	3	15.5	120	17	408.1	26	
Total	11	90.1	76	4	54.6	45	...	60.8	...	1	280.6	2.2	43	1 575.4	17	59	2 061.5	18	

	Percentage of fractures in the part covered by the fishplates	Percentage of fractures in the part clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails*	31 %	40 %	42	...	...	...	19
Medium rails	17 %	12 %	16	1	...	1	14
Total			58	1	...	1	33
Miles of single track of each class.			2 061	0.5		0.4	1 087

E. *a*), *b*) and *c*): No data.
d) Number of pieces rails are broken into: 2.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Length of single track with each rail profile.	Age of rails :											
		5 years and less.						5 to 10 years					
		Year of manu-facture.	Number of fractures			Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Year of manu-facture.	Number of fractures			Length of single track of this class.	Number of fractures per 1 000 km.
			In the length of the rail.	At the joint.	Total.				In the length of the rail.	At the joint.	Total.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Miles.					Miles.						Miles.	
BELGIUM.													
Belgian National Railway Company.													
Light rails :													
Weight : 38 kgr. (76.60 lb. per yard), profile adopted in 1863 (steel) and given up since.	90.7	...	...	...	...	...	...	...	...	...	...	...	...
Weight : 40.65 kgr. (81.94 lb. per yard), profile adopted in 1898 and given up since.	1 245.9	...	...	...	...	...	...	1921 to 1925	1	...	*1*	301.0	...
Medium rails :													
Weight : 50 kgr. (100.79 lb. per yard), profile adopted in 1910.	2 596.1	1926 to 1930	2	11	*13*	1 199.5	6.73	1921 to 1925	8 * 2	33 * 11	*41* * *13*	868.5	38.6
Weight : 52 kgr. (104.82 lb. per yard), profile adopted in 1886 and given up since.	167.2	...	...	...	...	...	...	...	...	...	...	...	...
Heavy rails :													
Weight : 57 kgr. (114.90 lb. per yard), profile adopted in 1907 and given up since.	260.8	...	...	...	...	...	...	...	...	...	...	...	...
Total. . .	4 323.8 * 36.9	...	2	11	*13*	1 199.5	...	...	11	44	*42* * *13*	969.5	...

Number of English ton-miles passengers and goods : 18 996 180 000.
Number of train-miles : 45 898 500.
Total number of fractures : 280.
Number of fractures per 10 000 000 train-kilometres or 6 250 000 train-miles : 37.9.
* In tunnels.

	Age of rails :																
10 to 15 years.						15 to 20 years.				more than 20 years.						Total number of fractures for the whole of the System.	Maximum axle load.
ear of anu- ture.	Number of fractures. In the length of the rail.	Number of fractures. At the joint.	Number of fractures. Total.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Year of manu- facture.	Number of fractures. In the length of the rail.	Number of fractures. At the joint.	Number of fractures. Total.	Year of manu- facture.	Number of fractures. In the length of the rail.	Number of fractures. At the joint.	Number of fractures. Total.	Length of single track with profiles 15 years old and over.	Number of fractures per 1 000 km. or per 625 m. of these classes (rails 15 years old and over).		
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
				Miles.										Miles.			Pounds.
..	...	...	...	...	...	...	...	...	...	...	2	...	2	90.7	13.7	2	
..	...	...	...	23.0	...	1911 to 1915	1	...	1	1898 to 1910	21	17 * 1	38 * 1	921.8	27.0	39 * 1	
919	3	10	13	217.5	37.0	1911 to 1915	11 * 2	40 * 9	51 * 11	...	3	13	16	310.7	156.0	134 * 24	52 250
..	...	...	...	...	...	...	...	...	...	1887 to 1908	1	4	5	167.2	...	5	
..	...	...	...	...	...	1911 to 1915	4	22 * 3	26 * 3	1907 to 1910	6	34 * 6	40 * 6	260.8	...	66 * 9	
	3	10	13	240.5	...	...	18	74	78 * 14	...	33	75	101 * 7	1 751.2	...	246 * 34	

Percentages of fractures		At the joint.	Outside the joint.
	I. *Light rails*	42.8	57.2
	II. *Medium rails*	80.3	19.7
	III. *Heavy rails*	86.6	13.4

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
French Nord Railway (Nord-Belge Lines).		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		
A. Rails outside tunnels — *Light*	...	...	...	...	...	...	...	3.85	...	...	0.19	...	...	9.29	...	...	13.34	...	...
Medium	...	78.49	...	...	36.24	...	...	0.65	...	...	35.47	...	3	32.21	58	3	183.06	10	...
Heavy	...	...	...	...	...	...	...	...	...	...	1.22	...	...	0.20	...	...	1.42	...	...
Total	...	78.49	...	...	36.24	...	...	4.50	...	...	36.88	...	3	41.70	45	3	197.82	9	...
B. Rails in tunnels — *Light*	...	...	...	...	...	...	...	...	...	...	...	..	...	0.08	...	...	0 08	...	...
Medium	...	1.29	...	1	0.48	1 282	...	...	...	1	0.57	1 083	...	0.05	...	2	2 40	517	...
Heavy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	...	1.29	...	1	0.48	1 282	...	...	...	1	0.57	1 083	...	0.13	...	2	2.48	500	...
C. The whole of A and B — *Light*	...	...	...	...	...	...	...	3.85	...	...	0.19	...	...	9.37	...	...	13.42	...	...
Medium	...	79.78	...	1	36.72	17	...	0.65	...	1	36.04	17	3	32.26	58	5	185.46	17	...
Heavy	...	...	...	...	...	...	...	...	...	...	1.22	...	...	...	...	...	1.42	...	...
Total	...	79 78	...	1	36.72	17	...	4.50	...	1	37.45	17	3	41.63	45	5	200.30	16	...

Number of train-miles: 2 257 225.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails*	...	...	...	...	...	...	...
Medium rails	40 %	60 %	3	1	1	5	...
Heavy rails	...	...	...	...	...	...	..
Total			3	1	1	5	...
Miles of single track of each class.			161.46	38.84		181.02	5.29

E.	*Light rails.*	*Medium rails.*	*Heavy rails.*
a) New clean fractures — with internal transverse fissure	...	...	...
a) New clean fractures — without internal transverse fissure	...	1	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the foot	...	2	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the head	...	2	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head — in the web	...	...	...
d) Number of pieces rails are broken into	...	2	...

NUMBER OF FRACTURES.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS				THE WHOLE OF THE RAILS.	*Maximum axle load.*
	5 to 10 years.	**10 to 15 years.**	**15 to 20 years.**	**More than 20 years.**		
1	2	3	4	5	6	7
National Light Railway Company.						English tons.
Rails outside tunnels. *Light*	3	16	21	682	722	10
Rails outside tunnels. *Medium*	6	24	12	...	42	
Total	9	40	33	682	764	

Number of train-miles : 26 284 475.

Number of fractures per 1 000 km. or per 625 miles for the whole of the rails : 164.
Number of fractures per 10 000 000 train-km. or 6 250 000 train-miles : 180.4.

Length of system worked : 2 878 miles.

Chimay Railway.	No rail breakages in 1930.
Malines-Terneuzen Railway.	No fractures on this line in 1930

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CONGO COLONY. Lower Congo to Katanga Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Engl. tons.
A. Rails outside tunnels. (*Light*) (9 lb) A *	4	93.2	26.6	1	3.2	200	...	227.4	...	3	211.3	9	...	...	...	8	535.1	9.29	14 8
B ■	2	697	1.78	...	...	...	...	...	...	...	...	...	...	...	...	2	697.2	1.78	14.8

Number of train-miles { A * : 1 677 700. B ■ : 683 500.

Number of gross ton-miles { A * : 232 395 500. B ■ : 70 085 500.

Number of fractures:
- Total { A * : 18. B ■ : 2.
- per 10 000 000 tr.-km. or 6 250 000 tr.-miles { A * : 30. B ■ : 18.
- per 1 billion tkm. or 612 000 000 Engl. ton-miles { A * : 21.05. B ■ : 17.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light* rails A *	3	5	2	6		6	2
B ■	...	2	1	1		2 (on level track)	...
Miles of single track of each class. A *			426.3	108.7		317.5	217.4
B ■			451.7	245.5		342.4 (stretches on the level included.)	354.8

E. —	LIGHT RAILS. A *	B ■
a) New clean fractures { with internal transverse fissure	...	...
without internal transverse fissure	2	2
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head { in the foot	3	...
in the head	2	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head { in the web	1	...
d) Number of pieces rails are broken into	2	2

A* = Bukama-Sakania Line; B ■ = Port-Francqui-Bukama Line (Léopoldville-Katanga-Dilolo Railway Company).

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					Miles.			Miles.			Miles.			Miles			Miles.		Pounds.
BRAZIL. Leopoldina Railway.																			
A. Rails outside tunnels — *Light*	...	...	...	1	258.75	2.4	...	...	...	5	69	45.2	104	1 539	42.2	110	1 866.75	36.8	23 020
B. Rails in tunnels — *Light*	...	...	...	...	1.25	...	...	...	...	...	...	...	...	...	...	...	1 25	...	...
C. The whole of A and B — *Light*	...	...	...	1	2.60	2.4	...	...	...	5	69	45.2	104	1 539	42.2	110	1 868	36.8	...

Number of train-miles: 5 584 605.

Number of English ton-miles: 578 670 816.

Number of fractures: total: 110.
per 10 000 000 train-km. or 6 250 000 trains-miles: 123.1.
per 1 billion tkm. or 612 000 000 English ton-miles: 116.3.

D and **E**, *a*), *b*), *c*), *d*). — No records.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rio Grande do Sul Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
Light rails outside tunnels (65-lb. per yard max.)	...	345.5	...	8	286.4	17	7	77.7	56	44	382.8	71	67	553	75	126	1 645.4	48	30 166 (4 6-2 locos).

Number of train-miles: 3 233 790.

Number of English ton-miles (gross): 696 945 534.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
			on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius.		on a rising or falling gradient.	
—	covered by the fishplates	clear of the fishplates		Lower rail.	Higher rail.	≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
Light rails	39 %	61 %	40	41	45	72	54

E. No records

Sorocabana Railway. — No exact records available.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
BULGARIA. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels } *Light*	...	252.3	...	2	78.7	15.8	13	134.3	60.1	1	106.5	5.8	31	991.0	19.4	47	1 562.8	18.6	13.8 (1)
B. Rails in tunnels } *Light*	...	4.7	...	...	...	...	...	...	...	...	0.4	...	1	4.9	1	1	10.0	...	
C The whole of A and B } *Light*	...	257.0	...	2	78.7	15.8	13	134.3	59.8	1	106.9	5.8	32	905.9	19.9	48	1 572.8	18.9	

Number of train-miles: 6 089 500.

Number of English ton-miles: 1 528 300 000.

Number of fractures { total: 48.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 49.
per 1 billion tkm. or 612 000 000 English ton-miles: 19.2.

(1) On the Sofia-Pernik and Zaribrod-Sarambey lines only, locomotives with 16.7-ton axle loads run.

	Percentage of fractures in the part covered by the fishplates	Percentage of fractures in the part clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails*	12.5	87.5	26	18	4	33	15
D. *Medium rails*	...	...	...	...	...	...	...
D. *Heavy rails*	...	...	...	...	...	...	...
		Total	26	18	4	33	15
		Miles of single track of each class.	1 153.3	419.5		1 144.4	428.4

E.	*Light rails.*	*Medium rails.*	*Heavy rails.*
a) New clean fractures { with internal transverse fissure / without internal transverse fissure	27	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head { in the foot	2	...	...
in the head	10	...	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head { in the web	9	...	...
d) Number of pieces rails are broken into	2	...	...

COLOMBIA. National Railway Company	Our track is of comparatively recent date and no rail breakages were reported except those due to derailments, landslips, etc.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			Total of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
DENMARK. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels *Light* . .	...	97.9	...	...	51	...	4	142.5	17.5	2	286.7	4 3	172	649.7	164.5	178	1 227.8	90.3	10.8-15.7
Medium .	...	124.9	...	...	124.6	. .	...	90.7	...	1	62.9	9.9	7	211.9	20.5	8	615	8.1	15 7
Total . . .	...	222.8	...	...	175.6	...	4	233.2	10.7	3	349.6	5.3	179	861.6	129.2	186	1.842.8	62.8	
B Rails in tunnels *Light* . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Medium .	...	...	...	...	...	...	...	...	...	...	4	...	...	...	...	...	4	...	...
Total . . .	...	...	...	...	...	...	...	...	...	...	4	...	...	...	...	...	4	...	
C. The whole of A and B *Light* . .	...	97.9	...	...	51	...	4	142.5	17.5	2	286.7	4.3	...	...	...	178	1 227.8	90.3	...
Medium .	...	124.9	...	...	124.6	...	...	90.7	...	1	66.9	9.9	...	...	...	8	619	8	...
Total . . .	...	222.8	...	...	175.6	...	4	233.2	10.7	3	353.6	5.3	179	861.6	129.2	186	1 846.8	62.7	

Number of train-miles 15 168 370 (1/1/30—31/12/30).

Number of English ton-miles 3 831 982 400 (1/4/29—31/3/30).

Number of fractures: total: 186.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 76.2.
per 1 billion tkm. or 612 000 000 English ton-miles: 29.7.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains radius. Lower rail.	on curves of ≤ 800 m. (40 chains radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails* . . .	73.2	26.8	98	41	38	82	...
Medium rails . .	87.5	12.5	8	0	1	5	...
		Total . . .	106	41	39	87	...

E.	*Light rails.*	*Medium rails.*
a) New clean fractures — with internal transverse fissure . . .	7	1
without internal transverse fissure . . .	45	1
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the foot . . .	34	3
in the head . . .	26	0
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head — in the web . . .	66	3
d) Number of pieces rails are broken into . . .	2 pieces: 164 3 pieces: 14	2 pieces: 5 3 pieces: 2 4 pieces: 1

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
EGYPT. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Rails outside tunnels. *Light*	...	...	...	...	...	...	...	...	...	...	...	...	16	730.1	13.61	16	730.1	13.61	18.85
Rails outside tunnels. *Medium*	...	553.6	...	1	210	2.98	...	62.8	...	4	262.2	9.47	6	1 523	8.58	11	2 611.6	4.48	18.85
Total	...	553.6	...	1	210	2.98	...	62.8	...	4	262.2	9.47	22	2 253.1	11.73	27	3 341.7	7.44	

Number of train-miles: 13 534 720.

Number of English ton-miles: 1 015 700 500.

Number of fractures: total: 27. per 10 000 000 tr.-km. or 6 250 000 train-miles: 12. per 1 billion tkm. or 612 000 000 English ton-miles: 16.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails*	1	15	16	...	...	9	7
D. *Medium rails*	1	10	10	1	...	9	2
Total			26	1	...	18	9

E. *a*), *b*), *c*), *d*). — No records. The necessary arrangements have been made for drawing up future statistics in the adopted form.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SPAIN. Central Aragon Railway.		Miles.			Miles.			Miles.			Miles			Miles.			Miles.		English tons
A. Rails outside tunnels 62.5 lb.	...	...	...	...	...	...	...	...	...	...	...	...	2	115.2	10.8	2	115.2	10.8	
80.6 lb.	...	4.7	...	...	3.7	...	...	...	...	...	...	...	...	...	...	...	8.4	...	
85.7 lb.	...	60.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	60.6	...	
Total	...	65.3	...	...	3.7	...	...	...	...	...	...	...	2	115.2	10.8	2	184.2	6.75	
B. Rails in tunnels 62.5 lb.	...	...	...	...	...	...	...	...	...	...	...	...	...	0.6	...	...	0.6	..	
80.6 lb.	...	...	...	...	0.1	...	...	...	...	...	...	...	...	...	...	...	0.1	...	15.3
85.7 lb.	...	0.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.9	...	
Total	...	0.9	...	...	0.1	...	...	...	...	...	...	...	...	0.6	...	..	1.6	...	
C. The whole of A and B 62.5 lb.	...	...	...	...	...	...	...	...	...	...	...	...	2	115.8	10.7	2	115.8	10.7	
80.6 lb.	...	4.7	...	...	3.8	...	...	...	...	...	...	...	...	...	...	...	8.5	...	
85.7 lb.	...	61.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	61.5	...	
Total	...	66.2	...	...	3.8	...	...	...	...	...	...	...	2	115.8	10.7	2	185.8	6.7	

Number of train-miles: 943 611.
Number of English ton-miles: 72 704 500.

Total number of fractures: 2.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. Rails 62.5 lb.	...	100	2	...	...	...	...
80.6 lb.	...	...	...	...	...	...	...
85.7 lb.	...	...	...	...	...	...	...
Total			2	...	...	...	...

	Light rails.	Medium rails.	Heavy rails.
E. a) New clean fractures with internal transverse fissure	...	...	...
without internal transverse fissure	2	...	...
d) Number of pieces rails are broken into	2	...	..

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Madrid-Saragossa-Alicante Railways.		Miles.			Miles.			Miles.			Miles.			Miles			Miles.		English tons.
A. Rails outside tunnels — *Light*	...	...	...	...	37.8	...	...	89.5	...	...	135.2	...	...	232.3	...	...	494.8	...	15.7
A. Rails outside tunnels — *Medium*	1	791.8	0.8	7	717.6	6.1	1	140.7	4.4	1	508.9	1.2	...	76.5	...	10	2 235.5	2.8	
Total	1	791.8	0.8	7	755.4	5.8	1	230.2	2 7	1	644.1	0.9	...	308.8	...	10	2 730.3	2.2	
B. Rails in tunnels — *Light*	..	...	...	...	...	...	...	0.2	...	...	1	...	...	...	...	...	1.2	...	...
B. Rails in tunnels — *Medium*	...	12.4	...	...	20	...	...	...	...	...	...	...	...	...	...	...	32.4	...	...
Total	...	12.4	...	...	20	...	...	0.2	...	...	1	...	...	...	...	...	33.6	...	...
C. The whole of A and B — *Light*	...	...	...	...	37.8	...	...	89.7	...	...	136.2	...	...	232.3	...	...	496	...	...
C. The whole of A and B — *Medium*	1	804.2	0.8	7	737.6	5.9	1	140.7	4.4	1	508.9	1.2	...	76.5	...	10	2 267 9	2.8	...
Total	1	804.2	0.8	7	755.4	5.8	1	230.4	2.7	1	645.1	0.9	...	308.8	...	10	2 763.9	2.2	...

Number of train-miles: 19 658 900.

Number of English ton-miles: 6 183 153 700.

Number of fractures { total: 10. per 10 000 000 tr.-km. or 6 250 000 train-miles: 3.16. per 1 billion tkm. or 612 000 000 English ton-miles: 0.989.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of $>$ 800 m. (40 chains) radius	on curves of $\leqslant$ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. $\leqslant$ 10 mm. per m (1 in 100)	$>$ 10 mm. per m. (1 in 100)
D. *Light rails*	...	...	...	...	...	..	...
D. *Medium rails*	...	10	6	4	...	3	6
Total	...	...	6	4	...	3	6
Miles of single track of each class.			149.1	2 131.3		1 180.6	609.6

		Light rails.	*Medium rails.*
E. a) New clean fractures	with internal transverse fissure	...	1
	without internal transverse fissure	...	1
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	...	1
	in the head	...	6
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	...	1
d) Number of pieces rails are broken into		...	2 pieces: 9.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Northern of Spain Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels — *Light* . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29	731.0	24.65	17.2
Medium .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	53	2 046.9	11.85	
Heavy. .	None in service.																		
Totaux . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	82	2 777.9	18.34	
B. Rails in tunnels — *Light* . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	10.3	60.38	
Medium .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16	77.6	128.14	
Heavy. .	None in service.																		
Totaux . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17	87.9	120.20	
C. The whole of A and B — *Light* . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30	741.3	25.14	
Medium .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	69	2 124.5	20.18	
Heavy. .	None in service.																		
Totaux . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	99	2 865.8	21.46	

Number of train-miles: 22 834 060.
Number of English ton-miles: 1 692 571 400.

Number of fractures { total: 99.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 27.5.
per 1 billion tkm. or 612 000 000 English ton-miles: 35.86.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails* . . .	10	90	26	3	4	9	6
Medium rails . .	24.64	75.36	43	11	12	31	20
Heavy rails . .	...	...	...	...	...	...	...
Total . . .			69	14	16	40	26
Miles of single track of each class.			2 293.4	572.4		1 253.2	628.2

		Light rails	*Medium rails*	*Heavy rails*
E. a) New clean fractures	with internal transverse fissure	2	12	None in service.
	without internal transverse fissure	14	32	
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	4	2	
	in the head	3	14	
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	7	9	
d) Number of pieces rails are broken into		2	2	

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Great Southern of Spain Railway (Ferrocarriles de Lorca a Baza y Aguilas).														Miles.			Miles.		English tons.
Rails outside tunnels. *Light*	...	...	...	...	...	...	...	...	...	...	...	...	11	123	56	11	123	56	13.7

Number of train-miles: 358 890.

Number of English ton-miles: 43 701 600.

Number of fractures { total: 11. per 10 000 000 tr.-km. or 6 250 000 train-miles: 190. per 1 billion tkm. or 612 000 000 English ton-miles: 154.

	Percentage of fractures in the part: covered by the fishplates	Percentage of fractures in the part: clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails* . . .	...	11	8	1	2	5	2
		Total . . .	8	1	2	5	2
		Miles of single track of each class.	99	24		23	52

E	*Light rails.*	*Medium rails.*	*Heavy rails.*
a) New clean fractures { with internal transverse fissure	...	...	...
a) New clean fractures { without internal transverse fissure	11	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head . . . . { in the foot	...	...	...
b) ... { in the head	...	...	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . . { in the web	...	...	...
d) Number of pieces rails are broken into	2	...	...

Ferrocarril Cantabrico.	On our lines, which are equipped with light rails over 20 years old, we have, properly speaking, no rail breakages. — Maximum axle load: 11.8 English tons. — Length of system: 65 miles.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
UNITED STATES OF AMERICA. **Baltimore and Ohio Railroad.**		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
A. Rails outside tunnels 100 lb.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
A. Rails outside tunnels 130 lb.	125	1156	68	26	210	77	...	...	...	...	...	...	...	...	...	151	1 366	69	
B. Rails in tunnels 100 lb.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
B. Rails in tunnels 130 lb.	8	9	560	...	...	...	...	...	...	...	...	...	...	...	...	8	9	560	70 000
C. The whole of A and B 100 lb.	157	1 518	65	196	1 018	120	112	582	120	129	286	282	12	71	106	606	3 475	109	
C. The whole of A and B 130 lb.	133	1 165	71	26	210	77	...	...	...	...	...	...	...	...	...	159	1 375	72	
Total	290	2 683	67	222	1 228	113	112	582	120	129	286	282	12	71	106	765	4 850	98	

* Number of train-miles : 33 466 500.

** Number of English ton-miles : 41 778 224 000 (gross).

Number of fractures { total : 765. per 10 000 000 tr.-km. or 6 250 000 train-miles : 143. per 1 billion tkm. or 612 000 000 English ton-miles : 11.2.

	Percentage of fractures in the part		NUMBER OF FRACTURES :				
	covered by the fishplates.	clear of the fishplates.	on straight lines or curves of 2° or under.	on curves of over 2°. Lower rail.	on curves of over 2°. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100).	on a rising or falling gradient. > 10 mm. per m. (1 in 100).
D. Rails 100 lb.	268 = 44 %	338 = 56 %	...	...	...	...	...
D. Rails 130 lb.	39 = 25 %	125 = 75 %	83	51	25	...	...
Miles of single track of each class (130 lb.).			825	275		...	...

		100-lb. rails.	*130-lb. rails.*
E. *a)* New clean fractures	with internal transverse fissure, both clean and rusted	284	110
	without internal transverse fissure, both clean and rusted	322	49
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot / in the head	Included under (*a*). Records do not separate.	
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	None.	None.
d) Number of pieces rails are broken into		Generally 2. More than 2 is exceptional.	

* 90 % of combined passenger and freight train-miles for system used — as properly equatable to 4 850 track-miles.

** [illegible] % of gross freight ton-miles of system (including engines and cabooses) used — as properly equatable to 4 850 track-miles.

BALTIMORE & OHIO RAILROAD (*Continued*).

The main facts in connection with the above table may be summarized as follows:

	100-lb. rail.	130-lb. rail.	Total.
Broken rails	606	159	765
Track-miles (included)	3 475	1 375	4 850
Failures per 625 track-miles	109	72	82
Failures per 6 250 000 train-miles			143
Failures per 612 000 000 ton-miles			11.2
Transverse fissures	284	110	394
Broken joints	268	39	307
Broken outside of joints	54	10	64
Total broken rails	606	159	765

	130-lb rail.
Broken on tangent or curves under 2 degrees:	
Per 625 track-miles	63
Broken on low side of curves over 2 degrees:	
Per 625 track-miles	115
Broken on high side of curves over 2 degrees:	
Per 625 track-miles	57

The comparison of rates of failures on straight track, low rails of curves, and high rails of curves is significant in bringing out the effect of tonnage. The relative high rate of breakage on the low side of curvesis undoubtedly due to the preponderance of weight placed on same by freight trains, where the track is elevated for passenger train speed.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Illinois Central System. (*)		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
90-lb. per yard, A. R. A.-A.	363	1 397	162	941	2 165	271	848	962	551	596	489	762	...	...	...	...	...	...	63 700
110-lb. per yard R. E.	40	435	57	18	101	111	...	...	...	...	...	...	...	...	...	...	...	...	63 700
Total.	403	1 832	137	959	2 266	264	848	962	551	596	489	762	...	...	...	...	...	...	...

* Year ending 31 October, 1930.

Percentage of breakage (covered by fishplate)	8.73	Number of train-miles: 34 554 000.
— — clear of fishplate	91.27	Total number of fractures: 2 806.
— — with silvery oval spot	23.12	Number of fractures per 6 250 000 train-miles: 508.
— — without silvery oval spot	76.88	

Note. — The fractures listed above include split heads, ordinary breaks, transverse fissures and horizontal split heads.

OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Delaware and Hudson Railroad.		Miles			Miles			Miles			Miles			Miles			Miles		Lb.
A. Rails outside tunnels. *Light*	...	...	...	...	0.43	...	...	11.70	...	...	26.23	...	2	187.68	6.6	2	226.04	5.5	66 500
Medium.	111	313.16	221.5	38	228.08	82.4	25	143.43	108.9	14	85.28	102.4	8	4.97	1 005.6	196	834.92	146.7	75 000
Heavy.	6	22.08	169.8	...	...	...	...	1.38	...	...	...	...	...	...	...	6	23.46	159.8	75 000
Total	117	335.24	218.1	38	288.51	82.3	25	156.51	99.8	14	111.51	78.4	10	192.65	324.8	204	1 084.42	117.6	
B Rails in tunnels. *Light*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Medium	...	...	...	...	0.91	...	...	...	...	...	...	...	...	...	...	...	0.91	...	75 000
Heavy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Total	...	...	...	...	0.91	...	...	...	...	...	...	...	...	...	...	...	0.91	...	
C The whole of A and B. *Light*	...	...	...	...	0.43	...	...	11.70	...	...	26.33	...	2	187.68	6.6	2	226.04	5.5	...
Medium	111	313.16	221.5	38	288.99	82.2	25	143.43	108.9	14	85.28	102.4	8	4.97	1 005.6	196	835.83	146.6	...
Heavy	6	22.08	169.8	...	...	...	...	1.38	...	..	...	...	...	...	...	6	23.46	159.8	...
Total	117	335.24	218.1	38	289.42	82.1	25	156.51	99.8	14	111.51	78.4	10	192.65	324.8	204	1 085.33	117.4	

Number of train-miles : 5 822 878.

Number of English ton-miles : 6 990 948 742.

Number of fractures: total : 204. per 10 000 000 tr.-km. or 6 250 000 train-miles : 218.94. per 1 billion tkm. or 612 000 000 English ton-miles : 17.858.

	Percentage of fractures in the part		NUMBER OF FRACTURES :				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	on curves of ⩽ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ⩽ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails.*	...	1	2	...	...	No record.	
Medium rails.	8.9 %	87.3 %	93	79	24		
Heavy rails.	...	2.8 %	3	1	2		
Total			98	80	26	...	...
Miles of single track of each class.			859.05	237.12		...	...

		Light rails.	*Medium rails.*	*Heavy rails.*
E. — *a)* New clean fractures	without internal transverse fissure	...	137	...
	with internal transverse fissure	2	59	6

b), c) and *d)* : No record.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS.															The whole of the rails.			*Maximum axle load.*
	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.						
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lehigh and New England Railroad.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Pounds.
A. Rails outside tunnels. *Medium* .	1	28	22	2	36	35	10	40	156	...	19	...	...	...	...	13	123	213	
A. Rails outside tunnels. *Heavy* . .	1	13	48	...	...	...	...	...	...	...	...	...	...	...	...	1	13	48	
Total . . .	2	41	70	2	36	35	10	40	156	...	19	...	...	...	...	14	136	261	
B. Rails in tunnels. *Medium* .	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	
B. Rails in tunnels. *Heavy* . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	73 000
Total . . .	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	
C. The whole of A and B. *Medium*	1	29	22	2	36	35	10	40	156	...	19	...	...	...	...	13	124	213	
C. The whole of A and B. *Heavy* . .	1	13	48	...	...	...	...	...	...	...	...	...	...	...	...	1	13	48	
Total . . .	2	42	70	2	36	35	10	40	156	...	19	...	...	...	...	14	137	261	

Number of train-miles : 531 393.

Number of fractures { total : 14. per 10 000 000 tr.-km. or 6 250 000 train-miles : 165.

	Percentage of fractures in the part		NUMBER OF FRACTURES :				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of $>$ 800 m. (40 chains) radius	on curves of $\leqslant$ 800 m. (40 chains) radius.		on a rising or falling gradient.	
				Lower rail.	Higher rail.	$\leqslant$ 10 mm. per m. (1 in 100)	$>$ 10 mm. per m. (1 in 100)
D. *Medium rails* . .	15	85	7	6	...	12	1
D. *Heavy rails* . .	...	100	...	1	...	...	1
		Total . . .	7	7	...	12	2

E. No data

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Norfolk & Western Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Pounds.
A. Rails outside tunnels. *Medium*	1	110	5.7	8	347	14.4	5	270	11.6	3	220	9	...	...	...	17	947	11.3	Steam locom.: 68 000
Heavy	57	959	37.5	44	571	48.1	...	...	...	...	...	...	...	...	...	101	1 530	41.3	Electric locom.: 75 000
Total . . .	58	1 069	33.8	52	918	35.4	5	270	11.6	3	220	9	...	...	...	118	2 477	30	

Number of train-miles: 14 220 091.

Number of English ton-miles: 33 248 000 000.

Number of fractures: total: 118.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 52.
per 1 billion tkm. or 612 000 000 English ton-miles: 2.17.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Medium rails* . .	23 %	77 %	11	3	3	...	...
Heavy rails . .	5 %	95 %	65	23	13	...	...
		Total . . .	77	26	16	...	...
		Miles of single track of each class.	1 300	866		...	...

		Medium rails.	*Heavy rails.*
E. *a)* New clean fractures	with internal transverse fissure . . .	11	65
	without internal transverse fissure . . .	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot . . .	...	...
	in the head . . .	2	32
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web . . .	4	4
d) Number of pieces rails are broken into . . .		2	2 and over.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Reading Company.																			
A. Rails outside tunnels *Medium*	1	...	...	4	...	...	...	...	...	3	...	...	2	...	...	10	...	...	
Heavy	47	...	...	47	...	...	...	...	...	...	...	...	...	...	...	94	...	...	
Total	48	...	...	51	...	...	...	...	...	3	...	...	2	...	...	104	...	...	
B. Rail in tunnels *Medium*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Heavy	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	
Total	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	
C The whole of A and B *Medium*	1	...	...	4	...	...	...	...	...	3	...	...	2	...	...	10	...	...	
Heavy	48	...	...	47	...	...	...	...	...	...	...	...	...	...	...	95	...	...	
Total	49	...	...	51	...	...	...	...	...	3	...	...	2		...	105	...	...	

	Percentage of fractures in the part covered by the fishplates	Percentage of fractures in the part clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Medium rails*	5	5	4	...	...	No record.	
Heavy rails	10	84	53	...	...		
		Total	57	...	...	...	...

	Medium rails.	*Heavy rails.*
E. *a)* New clean fractures with internal transverse fissure	1	67
without internal transverse fissure	9	28

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Richmond. Fredericksburg and Potomac Railroad.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
Rails outside tunnels. Medium .	...	...	...	7	85	51	...	...	...	...	...	...	...	...	...	7	85	51	70 000
Heavy.	7	141	31	...	...	...	...	..	...	...	...	...	...	...	...	7	141	31	
Total . . .	7	141	31	7	85	51	..	...	...	...	...	...	...	...	...	14	226	38.7	

Number of train-miles: 2 387 734.

Number of fractures { total: 14. per 10 000 000 tr.-km. or 6 250 000 train-miles: 36.4.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. Medium rails . .	57	43	7	None.		No grades as much as 1 in 100.	
Heavy rails . .	57	43	7				
Total . . .			14	...	...	...	...
Miles of single track of each class. . .			226	...	...	...	

		Light rails.	Medium rails.	Heavy rails.
E. a) New clean fractures	with internal transverse fissure	...	3	...
	without internal transverse fissure	...	4	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head :	in the foot	...	...	...
	in the head	...	...	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	...	...	...
d) Number of pieces rails are broken into		...	2	2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Wabash Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		Pounds
Rails outside tunnels. *Light* . .	...	...	...	...	...	...	...	...	...	30	136.5	137	328	745.4	275	358	881.9	254	69.500
Medium .	7	200	22	67	428.2	98	46	209.7	137	58	140.7	258	4	22.4	112	182	1 001	114	
Heavy. .	10	586.9	11	...	...	...	...	...	...	...	...	...	...	...	...	10	586.9	11	
Total . . .	17	786.9	13	67	428.2	98	46	209.7	137	88	277.2	199	332	767.8	271	550	2 469.8	139	

Number of train-miles: 14 127 425.

Number of English ton-miles: 5 568 242 260.

Number of fractures { total: 550.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 244.
per 1 billion tkm. or 612 000 000 English ton-miles: 60.5.

	Percentage of fractures in the part covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ⩽ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails* . . .	58	42	338	12		342	8
Medium rails . .	36	64	178	12		188	2
Heavy rails . .	20	80	10	...		10	...
Total . . .			526	24		540	10
Miles of single track of each class.			Information not available.				

E.	*Light rails.*	*Medium rails.*	*Heavy rails.*
a) New clean fractures { with internal transverse fissure	46	83	2
without internal transverse fissure	287	68	1
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head . . . . { in the foot	...	6	1
in the head	9	19	5
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . . } in the web	8	14	1
d) Number of pieces rails are broken into	No record.		

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
FINLAND. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		
Rails outside tunnels. Light	33	652.5	31	15	384.6	24	3	276.5	7	3	394	5	140	2 291.6	38	194	3 999.2	30	
Rails outside tunnels. Medium	...	117.4	...	...	130.5	...	...	33.6	...	...	57.8	...	...	...	...	...	339.3	...	
Total	33	769.9	27	15	515.1	18	3	310.1	6	3	451.8	4	140	2 291.8	38	194	4 338.5	28	

Number of train-miles: 14 118 095.

Number of English ton-miles: 973 616 260.

Number of fractures { total: 194.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 85.
per 1 billion tkm. or 612 000 000 English ton-miles: 122.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. Light rails	59	41	174	13	7	163	31
D. Medium rails	...	...	...	...	...	...	...
Total			174	13	7	163	31

	Light rails.	Medium rails.	Heavy rails.
E. a) New clean fractures with internal transverse fissure	5	...	...
a) New clean fractures without internal transverse fissure	24	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head: in the foot	97	...	...
b) in the head	24	...	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head: in the web	44	...	...
d) Number of pieces rails are broken into	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
FRANCE.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons
State Railways.																			
A. Rails outside tunnels. *Light*	...	12.0	...	1	76.4	8	...	20.0	..	13	879.0	9	244	4 401.0	35	258	5 388.4	30	
Medium	18	965.5	13	9	511.0	11	1	109.0	6	8	926.0	5	17	133.0	92	53	2 644.5	12	
Heavy	...	15.5	...	...	—	...	...	...	...	...	...	...	...	...	...	...	15.5	...	
Total	18	993 0	12	10	587.4	11	1	129 0	5	21	1 805 0	7	261	4 534.0	36	311	8 048.4	24	
B. Rails in tunnels. *Light*	...	...	...	...	...	...	...	0.6	...	...	...	...	2	2.0	667	2	2 6	500	
Medium	...	0.6	...	...	2.0	...	...	4.4	...	1	4.4	143	3	2.0	1 000	4	13.4	190	19.7
Heavy	...	28.0	...	...	10.6	...	...	...	...	...	...	...	...	...	...	...	38.6	...	
Total	...	28.6	...	...	12.6	...	..	5.0	...	1	4.4	143	5	4.0	833	6	54.6	69	
C. The whole of A and B. *Light*	...	12.0	...	1	76.4	8	...	20.6	...	13	879.0	9	246	4 403.0	35	260	5 391.0	30	
Medium	18	966.1	13	9	513.0	11	1	113.4	6	9	930.4	6	20	135.0	92	57	2 657.9	13	
Heavy	...	43.5	...	...	10.6	...	...	...	...	...	...	...	...	...	...	...	54.1	...	
Total	18	1 021.6	11	10	600.0	10	1	134 0	5	22	1 809 4	8	266	4 538.0	36	317	8 103.0	24	

Number of train-miles: 45 915 700.
Number of English ton-miles: 15 506 230 000.

Number of fractures { total: 317.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 43.
per 1 billion tkm. or 612 000 000 English ton-miles: 12.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails*	25	75	197	43	20	163	97
Medium rails	53	47	40	10	7	50	7
Heavy rails	...	...	...	...	...	...	...
Total			237	53	27	213	104
Miles of single track of each class.			6 945	1 158		7 068	1 035

E	Percentage *Light.*	*Medium.*
a) New clean fractures { with internal transverse fissure	20	9
without internal transverse fissure	34	12
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head { in the foot	14	7
in the head	15	26
c) Fractures with much rusted old part, *not* extending { in the web	17	46

d) Number of pieces rails are broken into	*Light.*	*Medium.*
2 pieces	240	52
3 —	12	2
4 —	2	3
5 —	1	...
6 —	3	...
7 —	1	...
8 —	1	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Alsace and Lorraine Railways (including the Guillaume-Luxembourg lines).		Miles.			Miles.			Miles.			Miles.			Miles.					English tons
Light rails	...	...	...	...	16.8	...	5	98.2	31	12	175.9	42	98	1 156.3	53	...	...	...	For wagons : 15.7
Medium rails . . .	2	291.3	4	3	288.3	6	5	32.9	94	21	82	159	24	205.9	73	...	...	...	For locomotives : 18.3.
Heavy rails	...	3.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Total . . .	2	294.5	4	3	305.1	6	10	131.1	47	33	257.9	80	122	1 362	56	...	...	...	

Number of train-miles : 19 770 500.
Total number of fractures : 170.

Number of fractures per 10 000 000 tr.-km. or 6 250 000 train-miles : 53.

	Percentage — Covered by the fishplates	Percentage — Clear of the fishplates.
A. — Fractures of light rails	75.7	24.3
— medium rails	90.9	9.1
— heavy rails	..	...

		Light. (Per cent)	*Medium.* (Per cent)	*Heavy.* (Per cent)
B. — *a*) Fresh and clean fracture in the whole of the rail section	with silvery oval mark	7	...	...
	without silvery oval mark	27.8	20	...
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot	15.7	12.7	...
	in the head	13	7.3	...
c) Fracture, part of which is old and much rusted, *not* extending to the outer surface of the foot or the head of the rail	in the web	36.5	60	...

d) Number of pieces the rail is broken into	2	3	4	5 (Pieces)	6	11	16
light . . .	78	26	7	1	2	...	1
medium . .	34	14	6	...	...	1	...
heavy . .	...	...	...	...	...	...	...

Note. — This table does not include broken *machined rails* in points and crossings, that is to say, those of the nose, wing rails, points and stock rails.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paris Circle Railways (*).		Miles			Miles			Miles			Miles			Miles			Miles		Engl. tons
A. Rails outside tunnels — *Light*	...	0.9	...	...	0.3	...	...	1.7	...	...	12.3	...	3	9.2	202	3	24.4	76.3	
Medium	1	70.9	8.8	2	40.0	31	...	6.7	...	1	5.7	108	...	0.8	...	4	123.1	20.2	
Heavy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Total	1	70.9	8.7	2	40.3	30.8	...	8.4	...	1	18.0	34.4	3	10.0	186	7	147.5	29.4	
B. Rails in tunnels — *Light*	...	...	...	...	...	...	...	...	...	...	0.5	...	...	...	...	...	0.5	...	18.9
Medium	...	0.2	...	...	0.3	...	...	0.9	...	...	...	...	...	...	...	...	1.4	...	
Heavy	...	...	...	...	1.8	...	...	...	...	...	...	...	...	...	...	...	5.3	...	
Total	...	0.2	...	...	2.1	...	...	0.9	...	...	0.5	...	...	...	...	...	7.2	...	
C. The whole of A and B — *Light*	...	0.9	...	...	0.3	...	...	1.7	...	...	12.8	...	3	9.2	202	3	24.9	74.7	
Medium	1	71.1	9	2	40.3	31	...	7.6	...	1	5.7	108	...	0.8	...	4	124.5	19.9	
Heavy	...	...	...	...	1.8	...	...	...	...	...	...	...	...	...	...	...	5.3	...	
Total	1	72.0	8.2	2	42.4	29.3	...	9.3	...	1	18.5	33.4	3	10.0	186	7	154.7	28	

Number of { train-miles : 1 824 420. English ton-miles : 825 550 300.

Number of fractures { total : 7. per 10 000 000 tr.-km. or 6 250 000 train-miles : 23.84. per 1 billion tkm. or 612 000 000 English ton-miles : 5.18.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails*	67	33	2	...	1	1	...
Medium rails	25	75	1	...	3	4	...
Heavy rails	...	...	...	...	...	...	...
Total			3	...	4	5	...
Miles of single track of each class.			113.6	41.1		138.2	16.5

		Light rails.	*Medium rails.*	*Heavy rails.*
		Percentage.		
E. *a)* New clean fractures	without internal transverse fissure	...	...	...
	with internal transverse fissure	33 %	50 %	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	...	...	...
	in the head	...	50 %	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	67 %	...	...
d) Number of pieces rails are broken into : 2.		...	...	...

* In running tracks (excluding points and crossings).

OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Est Railway. (1)		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		
A. Rails outside tunnels — *Light*	...	43.7	...	...	64.3	...	2	133.2	9.3	...	62.4	...	155	2 481.7	38.8	157	2 785.2	35	
Medium	2	699.4	1.8	3	384.4	4.8	6	354.4	10.5	9	314.6	17.7	123	1 262.4	60.5	143	3 015.2	29.4	
Heavy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Total	2	743.1	1.7	3	448.7	4.1	8	487.6	10.2	9	377	14.8	278	3 744.1	46.1	300	5 800.5	32.1	
B. Rails in tunnels — *Light*	...	...	...	...	...	...	...	0.1	...	...	...	...	...	4.5	...	...	4.6	...	
Medium	...	0.9	...	...	1.5	...	...	2.9	...	...	3.5	...	...	2.1	...	...	10.9	...	...
Heavy	...	8.2	...	2	16.8	74.1	...	...	...	...	...	...	...	...	...	2	25	49.7	
Total	...	9.1	...	2	18.3	68	...	3	...	...	3.5	...	...	6.6	...	2	40.5	30.6	
C. The whole of A and B — *Light*	...	43.7	...	...	64.3	...	2	133.3	9.3	...	62.4	...	155	2 486.2	38.7	157	2 789.9	34.9	
Medium	2	700.3	1.7	3	385.9	4.8	6	357.3	10.4	9	318.1	17.6	123	1 264.5	60.4	143	3 026.1	29.4	
Heavy	...	8.2	...	2	16.8	74.1	...	...	...	...	...	...	...	...	...	2	25	49.7	
Total	2	752.2	1.6	5	467	6.6	8	490.6	10.1	9	380.5	14.7	278	3 750.7	46.05	302	5 841	32.1	

Number of train-miles: 41 123 450.
Number of English ton-miles: 19 379 586 200.

Number of fractures { per 10 000 000 tr.-km. or 6 250 000 train-miles: 45.6.
per 1 billion tkm. or 612 000 000 English ton-miles: 9.5.

	Percentage of fractures in the part		NUMBER OF FRACTURES					d) Number of rails broken into			
	covered by the fishplates	clear of the fishplates	on straight lines of curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	on curves of ⩽ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient ⩽ 10 mm. per m. (1 in 100).	on a rising or falling gradient > 10 mm. per m. (1 in 100).	2	3	4	5
								pieces			
D. *Light rails*	22.3	77.7	79	43	35	85	12	144	11	2	...
Medium rails	73.8	26.2	113	24	6	93	...	120	18	4	1
Heavy rails	100	...	2	...	...	2	...	1	...	1	...
		Total	194	67	41	180	12				
		Miles of single track of each class	This information cannot be given for 1930.								

E.		*Light rails.*	*Medium rails.*	*Heavy rails.*
		Percentage		
a) New clean fractures	with internal transverse fissure	12.8	6.9	...
	without internal transverse fissure	45.9	29	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	17.8	11	...
	in the head	8.9	14.5	
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	14.6	38.6	100

(1) In running tracks, excluding points and crossings.
(2) 110 lb. per yard or over

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Midi Railway.		Miles.	[illegible]		Miles.			Miles.			Miles.			Miles.					English tons.
Light rails	...	4.4	...	...	...	...	...	...	...	42	313.2	83	194	1 927	63	...	...	...	17.7
Medium rails	1	327.5	2	23	499	29	27	315	53	7	52.8	82	...	...	...	...	...	...	17.7
Total .	1	331.9	2	23	499	29	27	315	53	49	366	83	194	1 927	63	...	...	...	

		Number of fractures.	Length of single track.	Number of fractures per 1 000 km. or 625 miles.
A. — Rails outside tunnels	light	229	...	...
	medium	55	...	...
B. — Rails in tunnels	light	7	...	...
	medium	3	...	...
C. — The whole of *A* and *B* . . .	light	236	2 244.6	65
	medium	58	1 194.3	30
		294	3 438.9	53

Number of train-miles: 21 707 725.

Number of English ton-miles: 9 310 875 100.

Number of fractures { total: 294.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 84.
per 1 billion tkm. or 612 000 000 English ton-miles: 19.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of $>$ 800 m. (40 chains) radius	on curves of $\leqslant$ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. $\leqslant$ 10 mm. per m. (1 in 100)	$>$ 10 mm. per m. (1 in 100)
D. *Light rails* . . .	77	23	183	31	22	111	51
Medium rails	78	22	56	1	1	29	1
Total . . .			239	32	23	140	52
Miles of single track of each class.			...	...		1 336	682.9

		Light rails.	*Medium rails.*
E. *a*) New clean fractures	with internal transverse fissure	6 %	3 %
	without internal transverse fissure	56 %	31 %
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	8 %	16 %
	in the head	8 %	10 %
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	22 %	40 %

		2 pieces.	3 pieces.	4 pieces.	Over 4 pieces.
d) Number of pieces rails are broken into	*Light* . .	202	22	5	7

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nord Railway.		Miles.			Miles.			Miles.			Miles.			Miles.					English tons.
Light rails.	...	...	...	...	...	...	2	316.8	3.9	...	33.1	...	129	686.9	116 7	...	...	...	18.5
Medium rails	...	488.2	...	18	444.6	25 2	2	553.6	2.2	15	400.3	23.3	63	1 035	37.8	...	...	...	18.5
Heavy rails	...	2.1	...	...	2.4	...	...	...	...	...	0.05	...	...	...	...	...	...	...	18.5
Total	...	490.3	...	18	447	25	4	870.4	2.8	15	433.45	21.5	192	1 721.9	69.3	...	...	...	...

Number of train-miles: 38 745 390.

Number of English ton-miles: 18 174 689 000.

Number of fractures:
- total: 229.
- per 10 000 000 tr.-km. or 6 250 000 train-miles: 37.
- per 1 billion tkm. or 612 000 000 English ton-miles: 8.

	Percentage: Covered by the fishplates.	Percentage: Clear of the fishplates.
A. — Fractures of light rails	24 %	76 %
— heavy rails	67 %	33 %
— medium rails	...	...

		Light rails. (Per cent)	*Medium rails.* (Per cent)	*Heavy rails.* (Per cent)
B. — *a)* Fresh and clean fracture in the whole of the rail section	with silvery oval mark	14.5	13.3	...
	without silvery oval mark	31.3	19.4	...
b) Fracture, part of which is old and much rusted, extending to the outer surface of the foot or the head of the rail	in the foot	26.7	24.5	...
	in the head	13.8	26.5	...
c) Fracture, part of which is old and much rusted, *not* extending to the outer surface of the foot or the head of the rail	in the web	13.7	16.3	...

d) Number of pieces into which the rail is broken	2	3	4	5	8
	pieces				
light	113	14	1	2	1
medium	68	23	2	3	2
heavy	...	...	...	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS : Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paris, Lyons and Mediterranean Railway (*)		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels *Light*	1	126.8	4.90	...	195.4	...	...	...	...	6	...	...	143	...	...	150	...	...	
Medium	12	1 055.4	7.06	19	575.4	20.51	5	...	...	34	...	...	12[illegible]	...	...	196	...	...	
Total	13	1 182.2	6.83	19	770.8	15.31	5	...	...	40	...	...	269	...	...	346	...	23.52	
B. Rails in tunnels *Light*	...	...	...	...	3.4	...	...	...	...	3	...	...	12	...	...	15	...	...	
Medium	3	33.9	55.04	61	29.2	1 297.86	47	...	...	6	...	...	7	...	...	124	...	...	18.5
Heavy	6	42.2	88.23	1	7.5	83.33	...	...	...	...	...	...	...	...	...	7	...	...	
Total	9	76.1	73.47	62	40.1	961.24	47	...	...	9	...	...	19	...	...	146	...	353.51	
C The whole of A and B *Light*	1	126.8	4.90	...	198.8	...	...	34.8	...	9	328.1	17.04	155	3 451.8	27.90	165	4 140.3	24.76	
Medium	15	1 089.3	8.55	80	604.6	82.22	52	381.5	84.69	40	1 309.2	18.98	133	1 822.5	45.34	320	5 207.1	38.18	
Heavy	6	42.2	88.23	1	7.5	83.33	...	...	...	...	...	...	...	...	...	7	49.7	87.15	
Total	22	1 258.2	10.86	81	810.9	62.06	52	416.3	77.61	49	1 637.3	18.59	288	5 274.3	33.93	492	9 397.1	32.53	

* Excluding points and crossings.

Number of train-miles : 76 324 165.

Number of English ton-miles : 33 201 106 700.

Number of fractures { total : 492.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 40.05.
per 1 billion tkm. or 612 000 000 English ton-miles : 9.06

	Fractures in the part: Covered by the fishplates.	Clear of the fishplates.	Rails broken into: 2 pieces.	3 pieces.	4 pieces.	5 pieces.	6 pieces.
Light rails	64= 38.78 %	101=61.22 %	138=83.64 %	16= 9.70 %	8=4.85 %	2=1.21 %	1=0.60 %
Medium rails	264= 82.5 %	56=17.5 %	214=66.88 %	68=21.25 %	31=9.69 %	6=1.87 %	1=0.31 %
Heavy rails	7=100 %	..	5=71.42 %	2=28.58 %	...	...	

	Fresh and clean fractures through the whole of the rail section.	Fractures partly old.	Fresh and clean fractures through the whole of the rail section: with oval mark.	without oval mark.	Fractures with old part extending to the outer surface: of the foot.	of the head.	Fractures with much rusted old part not extending to the outer surface of the foot or the head.
Light rails	96= 58.18 %	69=41.82 %	15=9.09 %	81= 49.10 %	22=13.33 %	14=8.48 %	33=20.00 %
Medium rails	212= 66.25 %	108=33.75 %	31=9.69 %	181= 56.56 %	22= 6.88 %	20=6.25 %	66=20.62 %

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paris-Orleans Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels — *Light*	...	...	...	1	...	...	...	...	...	2	...	...	20	...	...	23	3 690.4	3.8	
Medium	1	...	...	6	...	...	1	...	...	1	...	...	50	...	...	59	2 964.6	12.6	
Heavy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Total	1	...	...	7	...	...	1	...	...	3	...	...	70	...	...	82	6 655	7.6	
B. Rails in tunnels — *Light*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	18.7
Medium	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	1	8.7	71.4	
Heavy	...	...	...	4	...	...	1	...	...	...	...	...	...	...	...	5	67.7	45.8	
Total	...	...	...	5	...	...	1	...	...	...	...	...	...	...	...	6	76.4	56.9	
C. The whole of A and B — *Light*	...	...	...	1	...	...	...	...	...	2	...	...	20	...	...	23	3 690.4	3.8	
Medium	1	...	...	7	...	...	1	...	...	1	...	...	50	...	...	60	2 973.3	12.5	
Heavy	...	...	...	4	...	...	1	...	...	...	...	...	...	...	...	5	67.7	45.8	
Total	1	...	...	12	...	...	2	...	...	3	...	...	70	...	...	85	6 731.4	8.1	

Number of train-miles: 40 941 125.
Number of English ton-miles: 20 765 000 000.

Number of fractures: total: 88.
per 10 000 000 tr.-km. or 6 250 000 train-miles: 13.8.
per 1 billion tkm. or 612 000 000 English ton-miles: 2.6.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains' radius. — Lower rail.	on curves of ≤ 800 m. (40 chains' radius. — Higher rail.	on a rising or falling gradient. — ≤ 10 mm. per m (1 in 100)	on a rising or falling gradient. — > 10 mm. per m. (1 in 100)
D. *Light rails*	43.5	56.5	No data.				
Medium rails	34	66					
Heavy rails	100	...					

E.	*Light rails.*	*Medium rails.*	*Heavy rails.*
a) New clean fractures with internal transverse fissure	8.7 %	...	...
a) New clean fractures without internal transverse fissure	30.5 %	35.00 %	20.00 %
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the foot	21.7 %	21.7 %	60.00 %
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the head	21.7 %	28.3 %	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head — in the web	17.4 %	15.00 %	20.00 %
d) Number of pieces rails are broken into	2 pieces : 21 3 pieces : 1 4 pieces : 1	2 pieces : 55 3 pieces : 3 4 pieces : 2	2 pieces : 2 3 pieces : 2 ...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS : Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
Somain-Anzin-Belgian frontier Railway.	No rail breakages reported in 1930.																		
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Light Railways of the Landes.											Miles.			Miles.			Miles.		English tons.
Rails outside tunnels. *Light* . .	...	...	...	...	...	...	...	...	...	...	16.8	...	13	208.8	39	13	225.6	36	14.3

Number of train-miles : 354 750.

Number of English ton-miles (1).

Number of fractures { total : 13. per 10 000 000 tr.-km. or 6 250 000 train-miles : 227. per 1 billion tkm. or 612 000 000 English ton-miles (1).

(1) We are unable to supply this information for the year 1930, as our statistics only show the *useful* tonne-kilometres.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails.* . .	30	70	9	2	2	13	...
	Miles of single track of each class.		192	33.		197.6	28

E.		*Light rails.*
a) New clean fractures	with internal transverse fissure	...
	without internal transverse fissure	10
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	2
	in the head	1
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	...
d) Number of pieces rails are broken into		2

Société des Transports en Commun de la Région parisienne.	No statistics of rail breakages are kept; fractures occur rarely and generally have no serious consequences

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ALGERIA and TUNIS. Algerian State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels — *Light*	...	125.2	...	...	94.3	...	...	103.4	...	...	156.3	...	64	1 496	26	64	1 975.2	20	13.8
A. Rails outside tunnels — *Medium*	...	34.9	...	1	50	...	2	144.5	...	...	...	...	...	...	...	3	229.4	...	13.8
Total	...	160.1	...	1	144.3	...	2	247.9	...	...	156.3	...	64	1 496	26	67	2 204.6	18.8	
B. Rails in tunnels — *Light*	...	...	...	...	0.1	...	...	...	...	...	...	...	...	1.2	...	...	1.3	...	
B. Rails in tunnels — *Medium*	...	..	...	...	1.3	...	...	6.4	...	...	...	...	...	...	...	...	7.7	...	
Total	...	...	...	...	1.4	...	...	6.4	...	...	...	...	...	1.2	...	...	9	...	
C. The whole of A and B — *Light*	...	125.2	...	...	94.4	...	...	103.4	...	...	156.3	...	64	1 497.2	26	64	1 976.5	20	
C. The whole of A and B — *Medium*	...	34.9	...	1	51.3	...	2	150.9	...	...	...	...	...	...	...	3	237.1	...	
Total	...	160.1	...	1	145.7	...	2	254.3	...	...	156.3	...	64	1 497.2	26	67	2 213.6	18.8	

Number of train-miles : 8 786 635.

Number of English ton-miles : 1 334 921 800.

Number of fractures { total : 67.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 47.
per 1 billion tkm. or 612 000 000 English ton-miles : 30.

	Percentage of fractures in the part: covered by the fishplates	Percentage of fractures in the part: clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	NUMBER OF FRACTURES: on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	NUMBER OF FRACTURES: on curves of ⩽ 800 m. (40 chains) radius. Higher rail.	NUMBER OF FRACTURES: on a rising or falling gradient. ⩽ 10 mm. per m. (1 in 100)	NUMBER OF FRACTURES: on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails.*	15 %	80.5 %	35	19	10	36	12
D. *Medium rails.*	1.5 %	3 %	...	1	2	1	2
Total			35	20	12	37	14

E.	*Light rails.*	*Medium rails.*
a) New clean fractures — with internal transverse fissure	19	...
a) New clean fractures — without internal transverse fissure	24	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the foot	7	2
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the head	10	1
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head — in the web	4	...
d) Number of pieces rails are broken into	2 pieces : 63 3 pieces : 1	2 pieces.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS : Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Paris, Lyons and Mediterranean Railway. (Algerian system).		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A Rails outside tunnels *Light*	...	3.1	...	...	85.7	...	2	95.1	13	5	97.6	32	7	434.3	10	14	715.8	12	16.39
Medium	...	60.3	...	...	31	...	...	7.4	...	...	...	...	...	...	...	...	98.7	...	
Heavy	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Total	...	63.4	...	...	116.7	.	2	102.5	13	5	97.6	32	7	434.3	10	14	814.5	12	
B Rails in tunnels *Light*	...	...	...	...	...	...	...	0.6	...	...	...	...	2	5	250	2	5.6	222	
Medium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Heavy	...	...	...	...	1.2	...	...	...	...	...	...	...	...	...	...	...	1.2	...	
Total	...	...	...	...	1.2	...	...	0.6	...	...	...	...	2	5	250	2	6.8	222	
C. The whole of A and B *Light*	...	3 1	...	...	85.7	...	2	95.7	13	5	97.6	32	9	439.3	13	16	721.4	14	
Medium	...	60.3	..	...	31	...	...	7.4	...	...	...	..	...	...	...	...	98.7	...	
Heavy	...	...	...	...	1.2	...	...	...	...	...	...	...	...	...	...	...	1.2	...	
Total	...	63.4	...	...	117.9	...	2	103.1	13	5	97.6	32	9	439.3	13	16	821.3	14	

Number of train-miles : 2 748 840.

Number of English ton-miles : 180 594 200.

Number of fractures { total : 16.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 36.
per 1 billion tkm. or 612 000 000 English ton-miles : 54.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES : on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails.*	3	13	8	3	5	11	5
Medium rails.	...	...	...	...	...	...	...
Heavy rails.	...	...	...	...	...	...	...
Total			8	3	5	11	5
Miles of single track of each class.			683.5	137.8		653.5	167.8

	Light rails.	*Medium rails.*	*Heavy rails.*
E. a) New clean fractures { with internal transverse fissure	1	...	...
without internal transverse fissure	12	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head { in the foot	...	...	...
in the head	1	...	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head { in the web	1	...	...
d) Number of pieces rails are broken into	2	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
								Miles.			Miles.			Miles.			Miles.		English tons.
Compagnie des Phosphates et du Chemin de fer de Gafsa. *Light rails* outside tunnels. . . .	...	...	...	...	...	...	...	50.3	...	...	45.4	...	2	177.1	7	2	272.8	4.54	9.8

Number of train-miles: 18 950 620.

Number of English ton-miles: 5 021 256 500.

Number of fractures { total: 2. per 10 000 000 tr.-km. or 6 250 000 train-miles: 0.65. per 1 billion tkm. or 612 000 000 English ton-miles: 0.25.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ⩽ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails* . . .	...	2	On the straight.	...	...	1 (in 250 down gradient).	1 (in 66 down gradient).

E.	*Light rails.*	*Medium rails.*	*Heavy rails.*
a) New clean fractures { with internal transverse fissure	...	...	...
a) New clean fractures { without internal transverse fissure	1	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head . . . . . . { in the foot	1	...	...
b) { in the head	...	...	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . . { in the web	...	...	...
d) Number of pieces rails are broken into	2	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS : Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Compagnie fermière des Chemins de fer Tunisiens.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light* . A(*)	...	42.5	...	...	...	...	1	107.1	...	3	309.7	...	174	501.9	...	178	961.2	...	
B(*)	...	42.5	...	...	...	...	...	107.1	...	4	309.7	...	17	501.9	...	21	961.2	...	
Medium A	...	...	...	...	20.8	...	...	...	...	...	...	...	...	...	...	...	20.8	...	
B	...	...	...	...	20.8	...	...	...	...	...	...	...	...	...	...	...	20.8	...	
Total . . . A	...	42 5	...	...	20.8	...	1	107.1	...	3	309.7	...	174	501.9	...	178	982	...	
B	...	42.5	...	...	20.8	...	...	107.1	...	4	309.7	...	17	501.9	...	21	982	...	
B. Rails in tunnels. *Light* . . A	...	...	...	...	...	...	...	0.4	...	...	1	...	...	0.25	...	...	1.65	...	
B	...	...	...	...	...	...	...	0.4	...	...	1	...	...	0.25	...	...	1.65	...	
C. The whole of A and B *Light* . A	...	42.5	...	...	...	...	1	107.5	...	3	310.7	...	174	502.15	...	178	962.85	...	Standard gauge : 14.8 Narrows gauge : 11.8
B	...	42.5	...	...	...	...	...	107.5	...	4	310.7	...	17	502.15	...	21	962.85	...	
Medium A	...	...	...	...	20.8	...	...	...	...	...	...	...	...	...	...	...	20.8	...	
B	...	...	...	...	20.8	...	...	...	...	...	...	...	...	...	...	...	20.8	...	
Total . . . A	...	42 5	...	...	20.8	...	1	107.1	...	3	310.7	...	174	502.15	...	178	983.65	...	
B	...	42.5	...	...	20.8	...	...	107.1	...	4	310.7	...	17	502.15	...	21	983.65	...	

Number of train-miles : 3 302 000.

Number of English ton-miles : 747 710 380.

Number of fractures { total : 178 (+ 21 cracked rails).
per 10 000 000 tr.-km. or 6 250 000 train-miles : 336 (39 cracked).
per 1 billion tkm. or 612 000 000 English ton-miles : 146 (17 cracked).

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES : on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails* . A	30=17 %	148=83 %	172	4	2	4	1
B	7=33 %	14=66.6 %	16	...	5	1	...
	Miles of single track of each class.		874.8	108.85		754.25	229.4

		Light rails.
E. a) New clean fractures	with internal transverse fissure . . . . . / without internal transverse fissure	137
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	26
	in the head	12
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	3
d) Number of pieces rails are broken into		2

* In the above table rails under *A* are completely broken, those under *B* are only cracked.

OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Colonies and Protectorates. AFRICA. Colonial Railways of French West Africa.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Rails outside tunnels. Thiès-Niger (metre gauge)	...	42.3	...	...	124.3	...	...	44	...	4	197	12.61	45	399.5	69.98	49	803.2	37.75	9.8
Ivory Coast . .	2	65.3	...	...	85.1	...	...	...	...	1	83.3	...	...	113.1	...	3	346.8	...	11.8
Central Dahomey.	...	21.8	...	...	...	...	...	...	...	...	...	...	1	175.8	...	1	200.6	...	9.8

Number of train-miles { Thiès-Niger : 1 330 748. Ivory Coast : 616 117. Cent. Dahom. : 180 199. }

Number of Engl. ton-miles { Thiès-Niger : 63 653 857. Ivory Coast : 18 289 013. Centr. Dahom. : 73 739 463. }

Thiès-Niger : Number of fractures per 10 000 000 tr.-km. : 228.80; per 1 billion tkm. or 612 000 000 Engl. ton-miles : 470.77.

	Percentage of fractures in the part		NUMBER OF FRACTURES :				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	on curves of ⩽ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ⩽ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. Light rails. Thiès-Niger . .	3 = 6 %	46 = 94 %	37	5	7	43	6
Ivory Coast . .	...	3 = 100 %	...	1	2	2	1
Centr. Dahom. .	...	100 %	100 %	...	...	...	...
Miles of single track of each class (Thiès-Niger)			714.0	89.2		681.0	122.2

	LIGHT RAILS. Thiès-Niger.	LIGHT RAILS. Ivory Coast.	LIGHT RAILS. Central Dahomey.
E. a) New clean fractures { with internal transverse fissure.	2	1	...
E. a) New clean fractures { without internal transverse fissure	1	1	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head . . . . { in the foot	43	...	1
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head . . . . { in the head	3	1	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . . { in the web	...	...	...
d) Number of pieces rails are broken into.	2	2	2

East Dahomey Railway. No fractures in 1930. Length of system, 50 miles (outside tunnels).

Conakry-Niger Railway. No fractures in 1930.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
ASIA. Indo-Chinese Colonial Railways.								Miles.			Miles.			Miles.			Miles.		English tons.
Northern System.																			
Rails outside tunnels } *Light*	...	...	...	...	...	...	3	10.6	176.47	...	...	...	34	381.5	55.374	37	392.1	58.637	10.45
Southern System.																			
Rails onsides tunnels { *Light*	...	...	...	...	...	...	...	...	...	...	...	...	1	43.5	14.3	1	43.5	14.3	9.8
Rails onsides tunnels { *Medium*	...	...	...	...	...	...	...	...	...	9	262.4	21.3	...	...	...	9	262.4	21.3	...
Total	...	...	...	...	...	...	...	...	...	9	262.4	21.3	1	43.3	14.3	10	305.9	20.3	...

Number of train-miles { North : 1 481 928. South : 914 393.

Number of Engl. ton-miles } North : 53 244 020. South : 61 821 100.

Number of fractures per 10 000 000 tr.-km. or per 6 250 000 train-miles } North : 155.143. South : 68.

Number of fractures per 1 billion ton.-km. or per 612 000 000 English ton-miles (North) : 424.986.

	Percentage of fractures in the part: covered by the fishplates	clear of the fishplates	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains, radius. Lower rail.	Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100)
D. *Light rails* { North	10.81	89.19	32	1	4	3	2
Light rails { South	...	100.00	...	...	...	...	1
Medium rails	...	...	9	...	...	...	...
Miles of single track of each class (Northern system)			509.8	95.4	...	575.4	29.9

	Northern System. *Light rails.*	Southern System. *Light rails.*	Southern System. *Medium rails.*
E. *a)* New clean fractures { with internal transverse fissure	10	2	...
a) New clean fractures { without internal transverse fissure	12	2	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head { in the foot	11	...	...
b) { in the head	...	4	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head { in the foot	4	1	...
d) Number of pieces rails are broken into	10	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Djibouti Addis-Abeba Railway.								Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels } *Light* . .	...	...	...	...	...	...	2	146	8.51	...	147.9	...	2	193.2	6.43	4	483.1	5.10	9.3
B. Rails in tunnels } *Light* . .	...	...	...	..	...	...	...	...	...	...	...	...	...	0.9	...	...	0.9	...	
C. The whole of A and B } *Light* . .	...	...	...	...	...	...	2	146	8.51	...	147.9	...	...	194.1	6.43	4	484	5.10	

Number of train-miles: 575 180.

Number of English ton-miles: 31 579 100.

Number of fractures { total: 4. per 10 000 000 tr.-km. or 6 250 000 train-miles: 43.32. per 1 billion tkm. or 612 000 000 English ton-miles: 77.46.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ≤ 800 m. (40 chains) radius. Lower rail.	on curves of ≤ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ≤ 10 mm. per m. (1 in 100)	on a rising or falling gradient. > 10 mm. per m. (1 in 100)
D. *Light rails* . . .	...	100 %	...	4	...	...	4

E.	*Light rails.*
a) New clean fractures { with internal transverse fissure	..
a) New clean fractures { without internal transverse fissure	4
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head } in the head	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head } in the foot	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head } in the web	...
d) Number of pieces rails are broken into	2

Morocco Railway Company.

No fractures in 1930.
Total length of track: 359.5 miles, *i. e.* light rails — 326.5 miles of which 1.4 miles in tunnels; medium rails — 33 miles.
Number of train-miles: 5 412 680.
Number of English ton-miles: 903 621 800.
Maximum axle-load: 19.8 English tons.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Rails over 20 years old.			The whole of the rails			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8
ASIA MINOR.		Miles.			Miles.		English tons.
Damas-Hamah Railway and Extensions.							
Rails outside tunnels : *Light* . . . Beyrouth-Damas line : 27.620 kgr (55.7 lb. per yard) rails	4	91.2	...	4	91.2	10	12.48
Rayak-Halep line : 30 kgr. (60.5 lb. per yard) rails	2	206	...	2	206		12.99
Homs-Tripoli line : 30 kgr. (60.5 lb. per yard) rails	...	63.6	...	...	63.6		...
Total.	6	350.8	..	6	350 8		...

Number of train-miles : 749 280.

Number of English ton-miles : 98 317 035.

Number of fractures { total : 6; per 10 000 000 tr.-km. or 6 250 000 train-miles : 50; per 1 billion tkm. or 612 000 000 English ton-miles : 37.

	Percentage of fractures in the part		NUMBER OF FRACTURES :				
	covered by the fishplates	clear of the fishplates	on straight lines or curves of > 800 m. (40 chains) radius	on curves of ⩽ 800 m. (40 chains) radius. Lower rail.	on curves of ⩽ 800 m. (40 chains) radius. Higher rail.	on a rising or falling gradient. ⩽ 10 mm. per m. 1 in 100	on a rising or falling gradient. > 10 mm. per m. 1 in 100
D. *Light rails* . .	...	...	1	4	1	1	5
Miles of single track of each class.			247.6	103.2		122.6	124.6

		Light rails.
E. *a)* New clean fractures	with internal transverse fissure	1
	without internal transverse fissure	
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	1
	in the head	1
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	3
d) Number of pieces rails are broken into.		2 pieces : 4 3 pieces : 2

MISCELLANEOUS INFORMATION.

[836]

The Second International Steam-Table Conference. — Skeleton steam tables.

(From *Mechanical Engineering.*)

The second Steam-Table Conference was held in Berlin during the week commencing 23 June, 1930, in continuation of the first conference held in London in July, 1929, and reported in the February, 1930, issue of *Mechanical Engineering*, p. 120.

The Conference was opened on Monday, 23 June, by Prof. Dr. C. Matschoss, Director of the Verein deutscher Ingenieure, who in his introductory remarks referred feelingly to the loss sustained by the Conference through the death of Prof. H. L. Callendar, F. R. S. The proceedings then continued under the chairmanship of Prof W. Nernst.

After the necessary formal ess had been completed, it was decided, as ondon in 1929, to form a small committee to consider the actual revision of the values and enlargement of the skeleton tables.

Mr. I. V. Robinson was elected clairman of the Committee.

Some meetings of the Committee were also attended by Mr. Blomquist and Prof. Dr. Eichelberg, and also by other members of the various delegations.

The Committee held five meetings, and reported to the final Plenary Meeting of the Conference on the forenoon of Thursday, 26 June.

Using the 1929 skeleton steam tables as a basis, the Committee had revised these tables by the consideration of new experimental data, concerning which the different investigators had submitted short reports.

Thus the table of properties of saturated steam had been enlarged by including values for the properties of saturated water and steam at temperatures of 275 and 325° C. and in the table of the properties of superheated steam, values of the specific volume and total heat had been inserted for temperatures of 150, 250, and 350° C.

The additional experimental data available have thus made it possible to enlarge the skeleton tables so that they may serve as a more complete check to working tables prepared for the use of engineers.

The tolerances, which are still retained, permit flexibility in formulations made to serve as the basis for calculating complete working tables of the properties of steam.

In some instances smaller tolerances would have been justified by the close agreement of the different investigators, but it was deemed advisable not to reduce them too much at the present time, but to retain ample tolerances until such time as the various investigators are in still closer agreement

SATURATED STEAM. — ASSUMED VALUES AND TOLERANCES.

Saturation pressure and specific volume.

	Saturation pressure		Specific volume: Of liquid		Specific volume: Of vapor	
Temperature, degrees C.	Assumed value, kgr. per cm².	Tolerance, (±) kgr. per cm².	Assumed value, m³ per kgr.	Tolerance, (±) m³ per kgr.	Assumed value, m³ per kgr.	Tolerance, (±) m³ per kgr.
0	0.006225	0.000005	0.001000	0.000000	206.4	0.2
50	0.1258	0.0001	0.001012	0.000000	12.05	0.01
100	1.0332	0.0000	0.001043	0.000000	1.673	0.002
150	4.855	0.003	0.001090	0.000000	0.392	0.001
200	15.86	0.01	0.001156	0.000001	0.1273	0.0004
250	40.6	0.1	0.001252	0.000003	0.0502	0.0004
275	60.7	0.1	0.001317	0.000004	0.0329	0.0005
300	87.7	0.1	0.001403	0.000005	0.0215	0.0005
325	123.0	0.1	0.00153	0.00001	0.0142	0.0004
350	168.7	0.15	0.00174	0.00001	0.00875	0.00020

Total heat.

Temperature, degrees C.	Total heat — Of liquid — Assumed value, Int. kgr.-cal. per kgr.	Of liquid — Tolerance, (±) Int. kgr.-cal. per kgr.	Of vapor — Assumed value, Int. kgr.-cal. per kgr.	Of vapor — Tolerance, (±) Int. kgr.-cal. per kgr.
0	0	0	595.5	1.0
50	49.95	0.02	618.5	1.0
100	100.04	0.04	639.2	0.5
150	150.92	0.05	656.0	1.5
200	203.55	0.10	667.0	2.5
250	259.2	0.5	669	4
275	289.0	1.0	666	5
300	322	2	657	5
325	360	3	643	6
350	404	5	615	8

over the whole of the field covered by the skeleton tables.

The 1929 skeleton tables are superseded entirely by those attached to this report.

UNITS.

As in the 1929 tables, the following units have been used :

	Unit.	Symbol.
Length	Metre	m.
Specific volume	Cubic metres per kilogramme	m^3 per kgr.
Pressure	Kilogrammes per square centimetre . . .	kgr. per cm^2.
Temperature	Degree centigrade	degree C.
Total heat	International kilogr.-calorie, which by definition equals 1 kw-hr./860	kgr.-cal. per kgr.

Conversion factors.

No changes have been made in the values of the various conversion factors adopted at London and fully detailed in the 1929 report.

Values by definition.

Two values given in the skeleton steam tables are taken as exact by definition and therefore no tolerances are permissible. These values are for the total heat of saturated water under its own vapor at 0 deg. Cent., arbitrarily taken as equal to zero, and the pressure of saturated steam at 100° C. which is, by definiation, equal to 1.01325×10^6 dynes per cm^2. (1.0332 kgr. per cm^2.) in the specifications of the International Temperature Scale.

SUPERHEATED STEAM. — ASSUMED VALUES AND TOLERANCES.

Specific volume.

Temperature, degrees C.	Pressure 1 kgr. per cm^2. — Assumed value, m^3 per kgr.	1 kgr. per cm^2. — Tolerance, (±) m^3 per kgr.	5 kgr. per cm^2. — Assumed value, m^3 per kgr.	5 kgr. per cm^2. — Tolerance, (±) m^3 per kgr.	10 kgr. per cm^2. — Assumed value, m^3 per kgr.	10 kgr. per cm^2. — Tolerance, (±) m^3 per kgr.
100	1.730	0.003	...	...	...	...
150	1.974	0.003	...	...	...	...
200	2.214	0.003	0.4332	0.0005	0.2102	0.0003
250	2.452	0.003	0.4833	0.0005	0.2374	0.0003
300	2.689	0.004	0.5326	0.0005	0.2631	0.0003
350	2.925	0.004	0.5811	0.0005	0.2880	0.0003
400	3.161	0.005	0.6290	0.0005	0.3124	0.0003
450	3.396	0.005	0.6768	0.0005	0.3366	0.0003
500	3.632	0.005	0.7243	0.0005	0.3604	0.0004
550	3.868	0.005	0.7719	0.0005	0.3843	0.0005

	Pressure					
	25 kgr. per cm²		50 kgr. per cm²		100 kgr. per cm².	
250	0.0890	0.0003	...	...	...	...
300	0.1010	0.0003	0.0465	0.0004	...	...
350	0.1120	0.0003	0.0531	0.0004	0.0231	0.0005
400	0.1224	0.0003	0.0590	0.0003	0.0270	0.0005
450	0.1325	0.0003	0.0644	0.0003	0.0304	0.0004
500	0.1424	0.0004	0.0697	0.0004	0.0333	0.0005
550	0.1521	0.0005	0.0747	0.0005	0.0361	0.0005

	Pressure					
	150 kgr. per cm²		200 kgr. per cm²		250 kgr. per cm²	
350	0.0119	0.0005	...	...	...	...
400	0.0160	0.0005	0.01028	0.00005	0.00636	0.00005
450	0.0189	0.0004	0.01305	0.00030	0.00940	0.00015
500	0.0212	0.0004	0.01515	0.00035	0.01140	0.00025
550	0.0233	0.0005	0.01685	0.00040	0.01290	0.00040

Total heat.

Temperature degrees C.	Assumed value, Int. kgr.-cal. per kgr.	Tolerance, (±) Int. kgr.-cal. per kgr.	Assumed value, Int. kgr.-cal. per kgr.	Tolerance, (±) Int. kgr.-cal. per kgr.	Assumed value, Int. kgr.-cal. per kgr.	Tolerance, (±) Int. kgr.-cal per kgr.
	Pressure					
	1 kgr. per cm²		5 kgr. per cm²		10 kgr. per cm²	
100	639.4	0.5	...	...	...	...
150	663.5	1.0	...	...	...	...
200	687.0	1.5	682.5	1.5	676.0	1.5
250	711.0	2.0	707.5	2.0	703.0	2.0
300	735.0	2.0	732.5	2.0	729.5	2.0
350	759.0	2.0	757.0	2.0	755.0	2.0
400	783.5	2.0	781.5	2.0	780.0	2.0
450	808.0	2.0	807.0	2.0	805.5	2.0
500	833.0	2.0	832.0	2.0	831.0	2.0
550	858.0	2.0	857.5	2.0	857.0	2.0
	Pressure					
	25 kgr. per cm²		50 kgr. per cm²		100 kgr. per cm²	
250	689.0	2.0	...	...	...	...
300	719.5	2.0	700.0	3.0	...	...
350	747.5	2.0	734.0	2.5	701.5	3.0
400	775.0	2.0	765.0	2.5	742.5	2.5
450	801.5	2.0	793.5	2.5	777.5	2.5
500	827.5	2.5	822.5	2.5	810.0	2.5
550	854.0	3.0	850.5	3.5	841.0	4.0
	Pressure					
	150 kgr. per cm²		200 kgr. per cm²		250 kgr. per cm²	
350	648.5	4.0	...	...	...	...
400	715.0	2.5	676.0	2.5	623.0	4.0
450	759.0	2.5	737.0	3.0	710.0	5.0
500	796.5	2.5	782.0	4.0	765.0	5.0
550	830.5	4.0	820.0	6.0	807.0	10.0